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Preventing Illness and Injury in the Workplace

VOL. II—PART B: WORKING PAPERS

#9—The Personal Protective Equipment and Clothing Industry
#10—Report on Workplace Protective Equipment and Clothing
#11—Health and Safety Control Technologies in the Workplace: Accident Causation and Injury Control
#12—Computer-Teleconferencing as a Mechanism to Improve Information Transfer for Workplace Safety and Health
#13—Worker Training and Education Programs in Occupational Health and Safety

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Office of Technology Assessment
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PREFACE

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Preventing Illness and Injury in the Workplace

Volume II — Working Papers

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#9 — Gough, M., *The Personal Protective Equipment and Clothing Industry*, working paper, April 1984.

#10 — Springborn Management Services, Inc., *Report on Workplace Protective Equipment and Clothing*, contract report, August 1982.

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#12 — Priest, W. C., *Computer/Teleconferencing as a Mechanism to Improve Information Transfer for Workplace Safety and Health*, contract report, May 1983.

#13 — INFORM, *Worker Training and Education Programs in Occupational Health and Safety*, contract report, November 1983.

PREVENTING ILLNESS AND INJURY IN THE WORKPLACE

WORKING PAPER

THE PERSONAL PROTECTIVE EQUIPMENT AND CLOTHING INDUSTRY

by

MICHAEL GOUGH

Office of Technology Assessment
Congress of the United States of America

APRIL 1984

THE PERSONAL PROTECTIVE EQUIPMENT AND CLOTHING INDUSTRY

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Introduction

Personal protective equipment and clothing are generally regarded as the third leg of the triad of safety and health control technologies. Unlike engineering controls and, to some extent, administrative controls and educational programs, personal protection devices are not tailored to a particular workplace. Instead they are designed to provide protection against specified or general hazards regardless of the exact nature of the workplace. For instance, a hard hat protects against impacts whether from a falling object on a building contruction site or in a mine or in a shipyard.

Protective clothing — hats, masks, gloves, jackets, trousers, shoes — are accepted accoutements to many jobs, and respirators and hearing protection can provide protection against some hazards when no other controls are available. At the same time, use of respirators and hearing protectors is controversial in some situations.

Part of the attractiveness of personal protectiveon equipment is related to their apparent smaller cost as compared to engineering controls, their being available to protect against some newly found hazards at less trouble than retrofitting the workplace, and their usefulness in providing protection against hazards that may be present for a limited time. As an example, if a hazardous chemical that emits vapors and fumes is newly introduced into a workplace and the reaction vessel is open only for a few minutes a day, the appropriate respirator that protects the workers from that hazard would be preferred by the employer to refitting the workplace with engineering controls. On the other hand, workers complain about wearing respirators for long periods of the workday to protect against hazards that are ever present in the workplace, and there are questions about the effectiveness of respirators (see chapter 8[1]). Probably everyone finds himself somewhere between a position of preferring engineering controls for all exposures and respirators for all exposures. The arguments that swirl about questions of the correct position for OSHA, employers, and workers to take in choosing between engineering controls and respirators and other personal protective equipment are described in chapters 8 and 9.

This working paper discusses the products of the personal protection device and clothing industry. The industry is large. Sales of all personal protective equipment were estimated at $2.2 billion for 1981 (Springborn, 1982), respirator sales alone were $285 million in 1980 (Granville Corp., 1982), and millions of Americans use its products. Although most of the merchandizing of its wares is accomplished through advertizing directed at company officials and health and safety professionals, one company, 3M, has purchased full page ads in popular magazines such as the September 27, 1982 New Yorker drawing attention to its innovations in the development and production of personal protection devices and other health related products (see fig 1). To some extent, there is a spillover of protective devices to noncommercial applications such as home workshops, and people who do not use protective devices in their work may employ them in other tasks.

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[1] All references to chapter refer to the OTA report Preventing Illness and Injury in the Workplace.

Products of the Industry.

Personal protection devices can be grouped into eight categories (Springborn, 1982). Two types of equipment — respirators and hearing protection — can be substituted for engineering controls to reduce health risks. Other protective devices that, in effect, are specialized clothing are head protection, face protection, hand protection, and protective footwear, clothing, and eyewear.

Respirators

Various kinds of respirators are available to reduce risks from workplace atmospheres that contain toxic or disease producing gases, vapors or particulate matter, or that are deficient in oxygen. Specific respirators are, of course, designed to guard against particular risks. Considerations of the proper use and maintenance of repirators and conditions that contribute to less than optimal performance are discussed in chapter 8. Examples of different types of respirators are illustrated in chapter 8, figure 1. In general, respirators are either (1) air purifying or (2) atmosphere supplying.

Air Purifiying Respirators. Air purification is accomplished by mechanically filtering out particulate contaminants or by adsorption, absorption, chemical reactions or catalysis of vapors, fumes, and gases. Disposable respirators, "dust masks" provide a filter over the mouth and nose. They are light weight and widely used in many workplaces, from surgical operating rooms to reduce germ transmission to construction worksites to reduce inhalation of dusts. They are inexpensive, costing an average of $0.45, but sales are very large. In 1981, sales of such respirators amounted to $48 million, and sales are projected to increase at 8 to 9 percent per year over the next few years (table 1).

An air-purifying respirator is designed to admit air only through filters (figure 2). The filters are either a flat disk holding an electrostatic charge which attracts and holds particles or a loosly packed filter medium such as fiberglass. More complicated purifying respirators use blowers or compressors to pass contaminated air through the filter element. These respirators maintain a greater air pressure inside the facepiece than is present outside and any leakage, as a result of poor fit, should be outward. For that reason those respirators provide a guard against risks from less than optimal fit. In other types of air purifying respirators, the wearer's inhalation produces negative pressure in the mask. Ideally the reduced pressure draws air through the filter into the mask. Unfortunately, if the mask does not fit well, the reduced pressure will pull contaminated air into the mask from around its edges

Vapor and gas removing respirators have cartridges and canisters designed to remove specific contaminants from the air. Many Americans have had (unpleasant) experience with this type of personal protective equipment. The military gas mask, carried by recruits in Army basic training and Marine Corps boot camp, and generally use-tested by each recruit in a tear gas chamber, is remembered by millions.

Those individuals are probably not surprised that suppliers of industrial vapor and gas removing respirators reported that the most frequent complaints from users were about comfort (Springborn, 1982). Comfort is, of course, an important factor in safety; a comfortable, lightweight mask is more likely to be worn and to be worn properly.

Gases and vapors are removed by being adsorbed to the surface of a substance in a cartridge or canister or by being absorbed into a complex with chemicals in the cartridge or canister. Adsorption is instantaneous and highly efficient until all available sites for adsorption are filled by interacting contaminants. Absorption, which is a chemical reaction, requires longer times, and it ends when all the chemicals available to interact with the contaminants have been used up in chemical reactions.

Use of air-purifying respirators is ideally restricted to situations involving gases and vapors having a detectable odor or irritating effect. When the protective power of the cartridge or canister is exhausted, a smelly or irritating gas or vapor alerts the wearer. Otherwise there is no warning that the respirator is no longer protective.

The National Safety Council divides gas masks and canisters into 9 types for use against: (1) acid gases, (2) organic vapors, (3) ammonia gas, (4) carbon monoxide, (5) dust fumes, mists, fogs and smokes in combination with any gases or vapors in the first four categories, (6) combination acid gases and organic vapors, (7) combination acid gases, ammonia gas, and organic vapors, (8) combination acid gases and ammonia gas, and (9) universal against combinations of acid gases, organic vapors, ammonia, carbon monoxide and smokes. OSHA and NIOSH specify a different color code for each type of canister.

The last listed gas mask (9) is designed to purify air of particles as well as vapors. Manufacturers report that there is a demand for more multiuse canisters to reduce the number of canister changes now required as respirators are used in different environments (Springborn, 1982).

The useful life of a gas and vapor removing respirator is directly related to the amount of absorbing or adsorbing material, sorbent, that it contains. Cartridges (see picture of gas and vapor respirator, figure 2) contain between 50 and 200 cm^3 of sorbent; canisters are larger, those that are mounted on the "chin" of facemasks are 250 to 500 cm^3, those mounted on the back or chest of the wearer and attached by a hose to the facemask are 1,000 to 2,000 cm^3.

The Springborn (1982) survey of the market for respirators did not divide costs and sales figures between particle and gas and vapor purifying units, and the prices and market sizes quoted include both types of respirators. As is shown on table 1, reusable non-powered air purifying respirators cost an average of $15 each at the distributor level in 1981; powered air purifying respirators cost twenty times as much, $300. The total market for the former was $105 million; for the latter, $16.5 million.

Atmosphere Supplying Respirators. Atmosphere supplying respirators provide a supply of clean air or oxygen. They are of two types: (1) self-contained breathing apparatus, and (2) supplied air respirators (see figure 2). One or the other of these two types is indispensible for operations in oxygen deficient atmospheres.

The self-contained breathing apparatus resemble the SCUBA units used for free diving. They are equipped with a full facepiece and a supply of oxygen-sufficient gas, either from a tank of air or oxygen or from an oxygen generating solid, such as potassium superoxide.

Supplied air units are connected by hoses running from a mask facepiece, helmet, or full body suit to a source of compressed air in a clean environment. The diving suits familar to people alive in the 1940's and 1950's who witnessed life and death battles between giant clams or squids and divers looking for treasures during Saturday matinees are a marine analog to the supplied air units.

According to manufacturers, the most frequent user complaints about the self-contained units is their weight and bulk. For the air supply units, there are frequent complaints about the time required to attach hoses and the hampering of movements by the hose dragging behind the wearer.

Self-contained breathing apparatus cost distributors an average $650 each in 1981 and supplied air units $89. The total market for each was $55 million and $30 million respectively (see table 1).

Total respirator sales to distributors and direct sales from manufacturers to user companies in 1981 were about $272 million according to Springborn (1982). This number compares closely to the $285 million estimated by Granville Corp. (1982). Springborn (1982) lists 22 suppliers of respiratory protection, and Granville (1982) 29. Some of those firms, such as MSA, specialize in safety devices, while others, such as 3M and Bendix, are widely-diversified companies. Overall, respirator sales are expected to increase at a rate of about 6 percent annually, significantly faster than increases in employment. Springborn asserts that increased sales and the recent entry of new firms into the respirator market result from greater use of respirators because of regulatory requirements and efforts to avoid costs of engineering controls.

Granville (1982) states that respirators are among the most profitable of all personal protective equipment. For one firm, the gross profit margin on respirators was about 45 percent. Even allowing for 1 percent as advertizing costs and 6 percent as selling expenses, the net profit was still quite high at 38 percent.

Hearing Protection

Loud noise can lead to permanent hearing loss. Protection against loud noise is required by a 1971 OSHA standard that was modified in 1982. A discussion of the measurement of noise and the hearing protection standard is presented in chapter 8.

The simplest hearing protection devices are ear plugs which fit into the outer portion of the ear canal. According to manufacturer's advertizing, ear plugs are most effective in protecting against high frequency noise, the kind of noise most frequently encountered in the workplace. Ear plugs are made from silicone rubber, polyvinylchloride (PVC), polymer foams, waxed cotton, and mineral fibers. Many plugs are disposable, which avoids costs associated with cleaning and maintenance of resuable ear plugs. Hearing protection bands are essentially reusable earplugs attached to a springy framework that is worn over the head. Various types of hearing protective earmuffs are manufactured; some are designed to attach to hard hats and for other specialized uses.

Reducing the noise level that reachs the ears protects hearing, but it also reduces the ability of the worker to hear conversations, commands, and warning sounds. Communication devices incorporate earmuffs as protection against ambient noise and radio communication for conversation and commands.

Some brands of disposable ear plugs are sold in boxes of hundreds. Use of the plugs in the workplace is encouraged by the same techniques successfully used to sell many products. Attractive, young men and women smiling from the package sides apparently are intended to lead to the conclusion that use of the plugs will make the users young and attractive also.

Hearing protection industry sales in 1981 were estimated at $56.5 million at the distributor level. Somewhat more than a third of the dollar value of the market was in disposable plugs (see table 2). The market for hearing protection is expected to grow at 10 to 15 percent annually up to 1984 because of OSHA's 1982-promulgated hearing conservation program. Some manufacturers of hearing protective devices concentrate only in such products, but most companies manufacture hearing protection devices as part of a full line of safety devices.

The market for disposable ear plugs differs from that for most personal protective devices because the number of manufacturers is quite small. Two firms, EAR and Norton, split the $10 million dollar market at the distributor level for foam plugs. Two other firms, Bilsom and Flents account for 96 percent of the $ 3.5 million distributor-level market for all other disposable ear plugs.

The general competitiveness of the market for personal protection devices is better illustrated by the fact that 18 companies supply earmuffs in a market that totals $9 million. Overall 29 companies market hearing protection.

Eye Protection

Goggles, protective spectacles, and welding plates are designed to prevent damage that might be caused by foreign objects or by light of too great intensity or of a damaging wavelength reaching the eye. Protective eyewear, with the exception of transparent welders' plates that permit visibility out of welders' helmets, is grouped into three kinds — safety glasses with or without sideshields, goggles, and visitor's eyewear (see figure 3).

Safety glasses can be ground to the user's perscription if he or she wears corrective glasses or provided with no optical correction (plano lenses). Glass lenses offer good abrasion resistance and protection against some ultraviolet and infrared radiation. Plastic lenses are lighter, and provide greater impact resistance but scratch more readily. Plastic lenses can be made resistant to pitting from welding splatter and formulated to absorb ultraviolet radiation. The addition of sideshields to any safety glasses protects against particles entering from the side (see chapter 8).

Goggles protect against a variety of hazards including particles from chipping and grinding operations, chemical splashs, and ultraviolet and infrared radiation. Welding goggles protect against the particular hazards of that trade, splatter and intense ultraviolet, visible, and infrared radiation generated from high temperature metals.

Finally, visitor's eyewear is disposable glasses or goggles molded from cellulose propionate. They are designed to provide short-term protection, but they are not robust enough to be used full time in the workplace.

Because of the rapid replacement rate, there is a market for between 15 and 18 million pairs of plano protective glasses annually depending on the size of the workforce. The larger workforce of 1979 resulted in the purchase of 18 million pairs (worth $54 million); the smaller 1981 workforce with 15 million pairs (worth $48 million), and the 1982 market was projected to decrease by about 5 percent as the number of workers declined. Overall eye protection industry sales for glasses, goggles, and visitor's eyewear also fell, from $160 million in 1979 to $149 in 1981. Little long-term growth is expected in this market (Springborn, 1982).

Polycarbonate, which is 10 percent lighter than glass, has higher impact resistance, and can be coated with other substances to resist abrasion, is claiming an increasingly large share of the market. In 1975, 5 percent of plano safety glasses had polycarbonate lenses; in 1981, about 52 percent. Contributing to its successful penetration of the market is the fact that its price had remained constant for the 3 years through 1981.

Perscription safety glasses are made in smaller numbers (3.5 million in 1981), but, as would be expected, are significantly more expensive on a unit basis, $20 at the distributor level, as compared to about $3 for plano safety glasses. About 80 percent of perscription safety glasses have glass lenses, and the requirment for many molds to make perscription plastic lenses is expected to continue to impede the manufacture of plastic perscription lenses.

The 1981 market for goggles was about $25 million, and the largest segment was for chemical splash goggles. Visitor's safety eyewear totalled about $6 million in sales to distributors during the same year.

Many companies compete in the protective eyewear market. Springborn (1982) lists 18 companies that supply both glasses and goggles, 3 that supply glasses only, and 8 that supply goggles only. However the number of manufacturers of lenses is smaller; only 4 companies make polycarbonate lenses and 1 of those 4 plus 3 others are the only makers of glass lenses.

As is shown on table 3, more workers wear protective eyewear than any other protective clothing. In major mining industries (metals and bituminous coal), the chemical industry, electrical and electronic manufacturing, and public utilities (electric, gas, and sewer), more than 80 percent of employees are required to wear some sort of eye protection.

Head Protection

"Hard hats," are familiar to every sidewalk superintendant. Photographs from the World War II period show that wearing head protection was very much less common in those days. Protecting the head is now common in situations in which it was unheard of even a few years ago, including baseball batters, professional hockey players, and bicycle riders.

Industrial protective headware protects the worker from impacts with solid objects, acids and other chemicals, hot liquids and electrical shocks. All hard hats offer protection against concussion and have other safety features dependent upon the substances used in manufacture. Safety headware is classified into four groups by the American National Standards Institute (ANSI) and one commonly used type is unclassified:

Class A hardhats have limited voltage protection and are slow burning

Class B hard hats are designed for workers who may encounter significant electrical hazards. The headware has no metal parts, is slow burning and provides high voltage protection.

Class C hard hats offer no electrical resistance or flammability protection.

Class D hard hats are designed for fire fighters, offer electrical limited voltage protection and are made of self-extinguishing materials.

"Bump caps" protect workers from bumps or lacerations but not from falling or flying objects or electrical shock; they are essentially lightweight hard caps.

In 1981, the head protection market was approximately 9.5 million units and $26.6 million. Seventeen companies supply head protection. While 11 of the suppliers offer a variety of types of protective headware, 1 supplies only class B hats and 2 specialize in firefighters hats.

The size of this market is seen as being directly dependent on the state of the economy. The market is expected to increase apace with the slowly increasing numbers of non-agricultural workers.

Hand Protection

Gloves protect worker's hands from hazards such as heat, flames, sparks, chemicals, cutting and puncturing, abrasion, radiation, and electricity. Gloves used in the workplace include those used at home to protect against abrasions, cuts, and punctures and the familar "rubber gloves" of the kitchen sink and toilet bowl. Other gloves are made out of specially-resistant plastics, but they offer no protection against many workplace hazards (see chapter 8).

More than 70 companies, most of which are small, supply hand protection. The glove market has attracted imports, and, in 1981, 28.5 percent of fabric gloves, 73 percent of leather palm, and 17 percent of leather gloves were imported. The total number of pairs of gloves shipped to distributors was 944.4 million in 1981. Their value was $790 million.

Face Protection

Face shields are used to protect against hazards such as molten metal, chemical splashes, flying chips, intense heat, and light. Face protection devices may be worn attached to a hardhat, separately as a face shield or visor, hand held for short period use, or, like welding helmets, provide specialized eye protection as well as full face protection. Faceshields, in general, provide inadequate eye protection (see chapter 8), and ANSI recommends that eye protection be worn in conjunction with shields.

The total market for face protection in 1981 was $54 million at the distributor level. Twenty-two companies compete in that market. Eleven supply both faceshields and visors, one supplys only welding helmets, and 10 others supply both. Little growth is expected in this market during the next decade.

Protective Clothing

Clothing specifically for various workplaces is manufactured from many of the same materials that are used to make protective gloves. However, weight, comfort (especially "breathability"), and launderability are more important considerations in clothing.

A number of flame and heat resistant fabrics — DuPont's Nomex and Kelvar, Amatex's Nor-fab, Nutex's Zetex, Gentex's Preox, as well as aluminized fabrics — have been developed and are, to some extent, replacing asbestos in protective clothing. Despite progress made in providing new materials, asbestos is the only substance now available that provides protection from 2,000° F to 3,000° F heat.

Baker et al's (1982) study of workplace related deaths in Maryland found that 16/148 or 11 percent resulted from gunshot wounds. Ballistic Kelvar is used to make bulletproof vests for law enforcement officers, but it is unlikely that it would ever be common garb for taxi drivers (3 of whom were shot to death in Maryland in one year), grocery store owners (3), gas station operators (2) vendors workers (2) and one other worker who were not law enforcement officers and who were murdered in Maryland.

Gore-tex, which is manufactured by W.L. Gore Company, is a sandwich of polyester oxford on the outside, a layer of polytetrafluoroethylene in the middle, and polyester tricot on the inside. It resists penetration by liquid chemicals, "breaths," and allows moisture to evaporate. It is frequently used in clothing for firefighters. Nomex, which has better heat resistance, is the material most frequently used for the firefighters' "turnout clothing", which is the outer layer of protective clothing.

Disposable clothing is used to protect designated "clean rooms" from outside contamination and to protect workers by allowing them to leave their work clothes behind. Although generally designed for one-time use, some of this clothing is reused on a limited basis. It is made of various materials, polypropylene, polyethylene, plastic-coated cellulose, and lightweight plastics.

Outdoor workers require rainwear which is not very different from that sold to consumers. The same materials used for rainwear, rubber and various plastics, also provide protection against most chemicals.

Air supplied suits have been mentioned before in the discussion of respirators. They completely envelope the wearer and can be made of various manmade fabrics to resist liquids and vapors and to be gas proof (see figure 4). These suits are especially useful in emergency situations and in servicing and repairing damaged equipment that normally encloses or contains toxic materials.

The most promising protective clothing market from the standpoint of expected growth is in disposable clothing. Springborn (1982) reports some projections of increases of up to 10 percent annually.

Springborn (1982) found that more than 50 firms supply protective clothing. According to them, most of these manufacturers specialize in protective clothing, although some also offer hand protection, and still fewer a complete line of safety equipment. Seven firms supply 98 percent of all firefighters turnout clothing.

Foot Protection

Protective footwear is often equated with the "steel-toe," more correctly, safety-toe boot or shoe. In fact safety-toe footwear accounts for about 70 percent of the entire protective footwear market. Safety toe footwear provides a cage of steel or other metal around the toe or the toe and metatarsal area to protect against compression injuries. Puncture resistant soles protect against penetration from the bottom of the foot and are familar to servicemen from the Vietnam War era.

A relatively new market is now opening up to the protective footwear industry. The growing number of women working in what were traditionally male trades has created a demand for smaller, lighter shoes, and increasingly for more stylish shoes, according to Springborn (1982).

Some 22 manufacturers supply the protective footwear market. Of those, only 4 produce any significant amount of other protective equipment. Those four, Rainfair, Uniroyal, Record, and B.F. Goodrich, produce molded footwear and other protective clothing made from rubber and PVC.

Six companies make only leather protective footwear and an additional six make both leather and molded footwear. The 9.5 million pairs of leather protective footwear sold in 1981 were worth $335 million at the distributor level. Approximately 7.6 million pairs of molded boots, worth $168 million, were sold in the same year. In 1981, about 70 to 75 percent of the total market for molded boots was for rubber boots, but PVC is significantly cheaper than rubber ($10.50 a pair vs. $25.00 a pair). Manufacturers estimate that PVC will account for 50 percent of the market by 1986.

The overall protective footwear market increased at a 2 percent annual rate during the 1970's. However domestic protective footwear manufacturers steadily lost ground against imports in that decade. In 1970, 30 percent of protective footwear was imported; in 1979, 53 percent. Importers are especially important in the molded PVC boot market.

Merchandizing and Distribution of Personal Protective Equipment and Clothing

The bulk of personal protection device marketing is conducted through distributors. Springborn (1982) estimated that there were more than 500 safety product distributors in the United States. One large manufacturer, MSA, which supplys safety items in every category except gloves and shoes, sells only directly to users. More typical are other large manufacturers/suppliers who sell mainly through distributors but also sell to larger users through their own sales organization.

Distributors stock, sell, and service personal protective equipment. Because of their proximity to the users, distributors often are the immediate recipient of complaints and suggestions about particular lines of equipment.

Brand names play a major role in distributors' selling. Advertizing by the manufacturers/suppliers in appropriate newspapers and magazines and in distributors' catalogs heightens brand name recognition. According to Springborn, brand names are frequently requested when equipment is being replaced, reflecting general satisfaction with the product being replaced.

Granville's (1982) findings for the respirator industry confirm the general impression about the importance of brand names. Respirator sales are made to distributors, but a large market is from manufacturers directly to user companies. Product recognition and service are the main factors in competition among respirator manufacturers. There is little competition through price, advertizing, or technology. There is also no evidence of price collusion.

Much of the technical advice for the use of protective clothing and devices is provided by the manufacturers to the distributors. The distributors, in turn, provide information along with the items they sell. Such transfers of information are common in many industries, however, no information is available to judge how accurately or completely, necessary and desirable technical information is transferred by this system. If the market works well, both better products and better distributors will be favored, but evidence from the Springborn survey about respirators suggests that the market may not be a critical judge of technical performance.

Springborn asked repirator manufacturers about what complaints they most frequently receive about their products. Most "users," which in the Springborn survey were employers who purchased the equipment, not workers who wore it, voiced no complaints about respirators, and Springborn states that really dissatisfied users probably do not bother to complain, but simply do not purchase the product again. The most frequent complaints dealt with comfort. No complaints were noted about the effectiveness of respirators. Absence of concern about how well respirators work, at both the manufacturer and purchaser level, is to be contrasted to the criticisms directed at respirator performance as a result of evaluations of the devices (see chapter 8).

Future Prospects for the Personal Protection Equipment and Clothing Market

The Bureau of the Census estimates the value of shipments of protective equipment every 5 years. The Bureau's data for 1972 and 1977 are shown in table 4. The breakdown of categories is not the same as the framework for this working paper, but the data show that there was a 5.5 percent increase in the value of shipments during those five years. Shipments of both eye and face protection devices decreased while those of respirators, clothing, and other devices increased.

Springborn (1982) estimated the 1981 market and projected the 1986 market. Those data predict an overall increase of 3 percent annually with some increase in every category. Those estimates were derived from a survey of personal protection device manufacturers/suppliers and purchaser companies and may reflect an inherent optimism about the economy in general and some markets in particular. Granville (1982) estimated a comparable increase in the respirator market. For 1985, Granville estimates a market of between $328 and $504 million.

To a major extent, market fortunes are expected to parallel changes in the number of people in the work force. The workforce is expected to increase less between 1980 and 1990, 1.5 percent, than it did between 1970 and 1980, 2.35 percent. Because much of the protective clothing and device industry produces items for blue collar workers, the fact that that workforce is expected to grow 1.2 percent in the 1980's as compared to a 1.6 percent growth in the 1970's lends credence to the conclusion that the market will not increase so much in the coming decade as it did during the last decade.

Increasing concern about workplace hazards or recognition of additional hazards or more emphasis on personal protection devices as opposed to engineering controls would, of course, have a positive effect on the market.

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Table 1
Sales of Respiratory Protection Devices for 1981

	Mil Units	Average Cost/Unit
Disposable	107	$ 0.45
Nuisance Dust Mask	80	$ 0.22
Reusable Non-powered Air Purifying	7	$ 15.00
Powered Air-Purifying	.05	$300.00
Self-Contained Breathing Apparatus	.85	$650.00
Supplied Air, Not Including SCBA	.34	$ 89.00

Table 2
The Hearing Protection Market for 1981

	Market Size Million $	Average Cost
Reusable Plugs		
PVC Plugs	2.7	$0.50 / pair
Silicone Rubber Plugs	2.4	$0.60 / pair
Disposable Plugs		
Disposable Foam Plugs	10.0	$0.13 / pair
Other Disposable Plugs	3.5	$0.05 / pair
Bands	2.5	$3.75
Muffs	9.0	$7.50
Communication Devices	7.0	Varies

Table 3
Millions of Workers Wearing Protective Equipment

Total Number of Workers	Eye	Foot	Head	Hand	Hearing	Clothing	Respiratory	Face
26.3	15.2	13.5	11.3	10.2	7.5	2.5	2.0	1.6

Workers in SIC codes 8,10-14,20-28, 30-39 and 49, (the forestry, mining, construction, manufacturing, and public utility industries).

Table 4
Value of Shipments of Personal Protective Equipment and Clothing in 1972 and 1977

	Current Dollars (Millions of $)		Constant Dollars (Millions of $)		% Annual Difference
	1977	1972	1977	1972	
Personal industrial safety devices-SIC Code 38423	403.1	226.0	288.3	226.0	5.5
- Respiratory protection equipment including gas masks, abrasive masks, canister masks, etc.	127.5	56.5	91.2	56.5	12.0
- Eye and face protection devices including face shields, hoods, and welding helmets and masks but excluding industrial goggles and eye protectors	44.1	37.8	31.54	37.8	-3.0
- Protective clothing, except shoes	68.4	48.4	48.93	48.4	0
- Other personal safety devices	119.6	65.8	85.55	65.8	6.0
- Personal industrial safety devices not otherwise classified	19.9	6.6	14.23	6.6	23.0
Industrial goggles, eye protectors, welding circles and plates, mounting and parts-SIC Code 38513	48.5	36.6	34.69	36.6	-1.0

Source: Springborn (1982) from Bureau of the Census Data.

Figure .1

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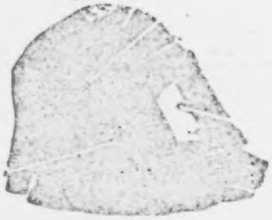
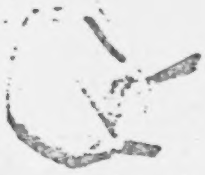
Photo courtesy 3M, Occupational Health & Safety Products Division

SPRINGBORN MANAGEMENT SERVICES INC

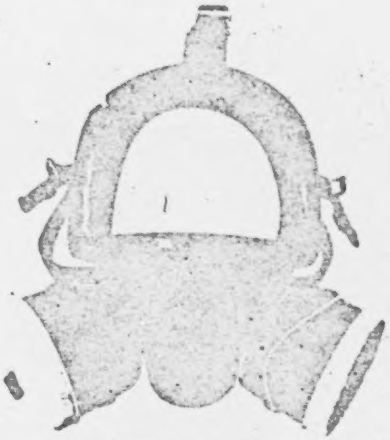
Figure 2
Respiratory Protection Devices



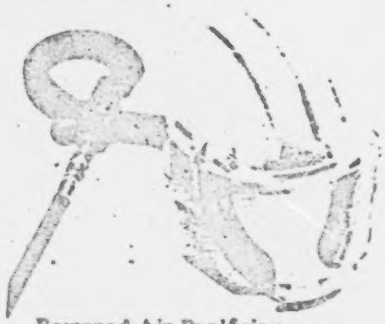
Abrasive Blasting
Helmet by 3M



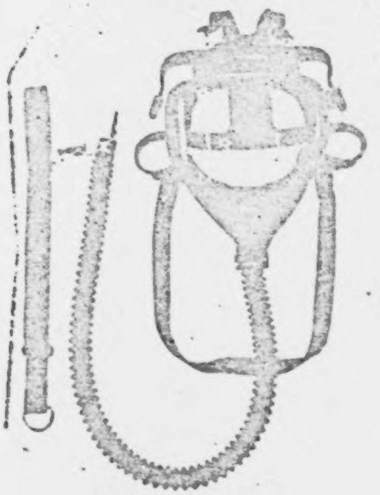
Disposable
Respirator
by 3M



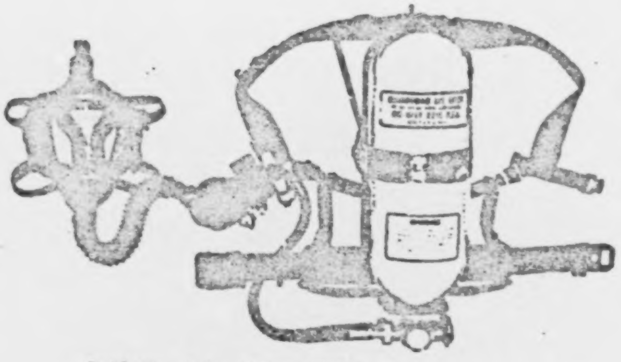
Reusable Air-Purifying
Respirator by Cesco



Powered Air Purifying
Helmet by Racal



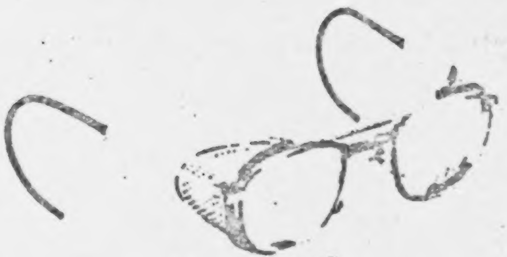
Airline Respirator
by Willson



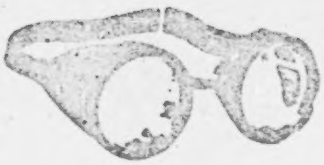
Self-Contained Breathing
Apparatus by Globe

Figure 3

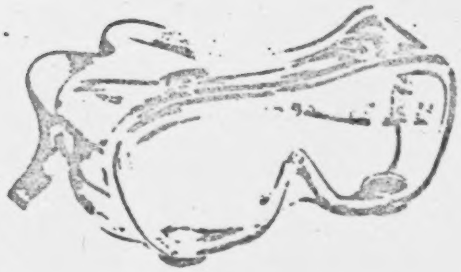
Protective Eyewear



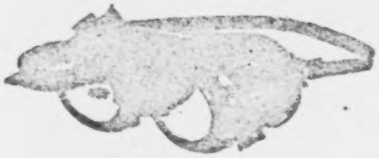
Safety Glasses with Sideshields



Cup Goggle



Chemical Splash Goggle



Welder's Goggle

Source: U.S. Safety Service

Figure
4

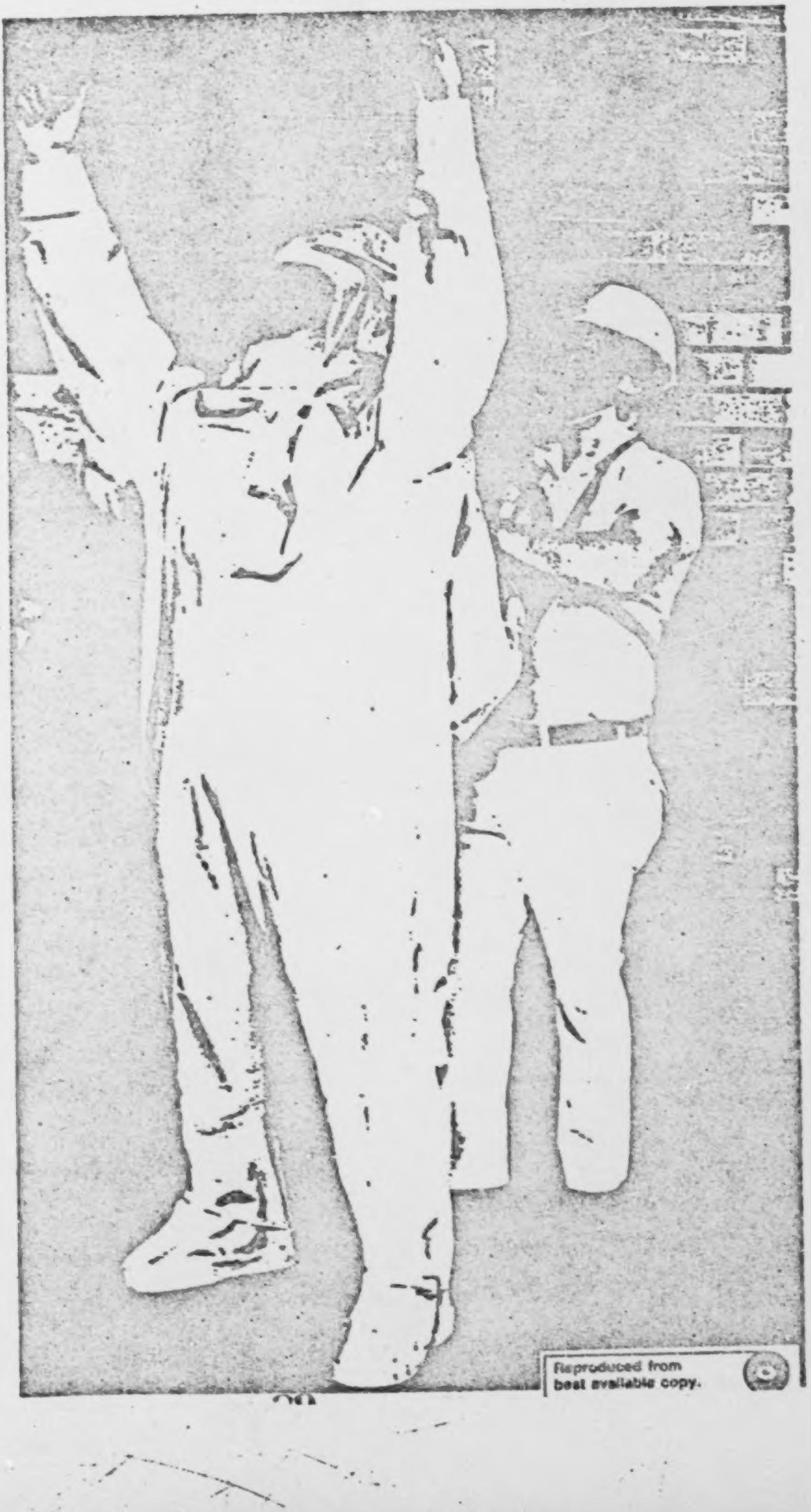


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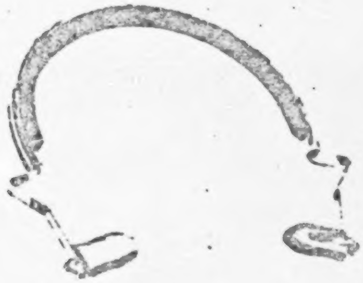
Figure 5

Various Types of Ear Plugs

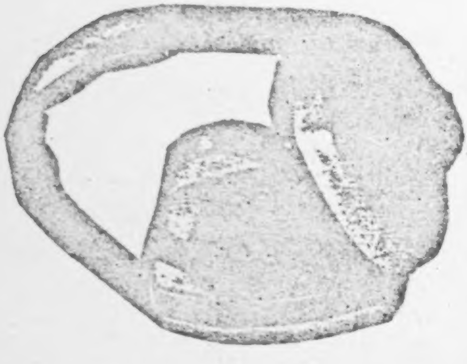
Disposable Plugs by EAR

Disposable plugs
by Bilsom

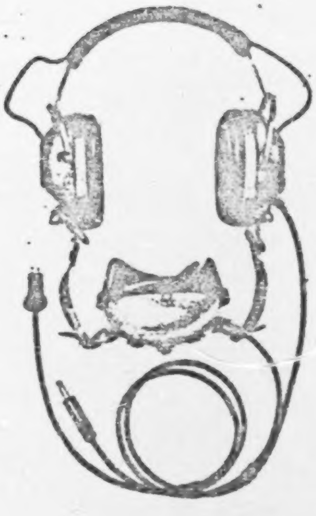
Reusable Plugs by American Optical



Band by Willson



Earmuffs by Bilsom



Communication Device

REPORT ON WORKPLACE PROTECTIVE EQUIPMENT AND CLOTHING

DRAFT

Prepared for

OFFICE OF TECHNOLOGY ASSESSMENT
WASHINGTON, D.C. 20510

JUNE 22, 1982

Prepared by

SPRINGBORN MANAGEMENT SERVICES, INC.
ENFIELD, CONNECTICUT 06082

Contract No. 233-4400.0

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PREFACE

The attached document is a contractor's study done under the supervision and review of the Office of Technology Assessment (OTA) of the Congress of the United States. The purpose of the study is to provide information in support of the OTA assessment of health and safety control technologies in the workplace.

This report was submitted in fulfillment of Contract Number 233-4400.0 by Springborn Management Services, Inc. Work was completed as of July 1982.

EXECUTIVE SUMMARY

THE PERSONAL PROTECTIVE EQUIPMENT AND CLOTHING MARKET

The personal protective equipment and clothing market includes the following segments: respiratory protection, head protection, face protection, hand protection, protective footwear, protective clothing, hearing protection and protective eyewear. The eye, face, head, hand and foot protection segments are saturated and growth will be dependent on the rise in industrial employment. Other segments should grow at a faster rate with hearing protection forecasted to grow at 10-15% annually through 1984, respiratory protection at 6% and protective clothing at 5.5%. Overall growth of personal protective equipment and clothing is estimated at 3.4%/year.

Growth potential is recognized for such areas as respiratory protection in the textile industry, hearing protection in the lumber, printing and metal industries and protective clothing in the rubber, plastics and chemical industries.

In 1977, the U.S. Bureau of Census reported the value of manufacturers' shipments at $400 million. The 1981 market was estimated at $2.2 billion and consumption in 1986 is projected to reach over $2.5 billion. The following table provides estimates of the consumption of protective equipment in the various market segments.

Consumption of Personal Protective Equipment

	1981 Million $	1986* Million $
Hand Protection	790	868.0
Foot Protection	503	583 1
Protective Clothing	315	411.7
Respiratory Protection	272	364.0
Protective Eyewear	149	156.6
Face Protection	55	57.8
Hearing Protection	37	66.7
Head Protection	28	30.3
	2,149	2,538.2

*In constant 1981 dollars

Significant penetration of the market is experienced in protective footwear, protective clothing and hand protection. There are nearly 150 suppliers of personal protective equipment and clothing and over 300 distributors. Factors which greatly affect the market are industrial employment levels, government regulations, and competitive marketing strategies of the various suppliers and distributors.

For each segment of the market, this study details the types of equipment, the testing standards required, the size of the market, the major suppliers and their market shares, and market saturation by industry SIC Code.

IMPROVEMENTS IN PERSONAL PROTECTIVE EQUIPMENT

According to the equipment users, distributors and manufacturers contacted, factors which greatly impact worker use/non-use of protective equipment are comfort, enforcement of regulations, and worker education and training.

Dissatisfaction with respirators related more to comfort than to performance. Some respirators were described as heavy, hot, and ill-fitting. No manufacturer claims to offer a laminar flow helmet and most users were unfamiliar with the term.

Current research and development with respirators involves more comfortable, lighter-weight materials, disposable respirators, different size facepieces, and a broadened range of applications of the cartridge.

SECTION I

OVERVIEW AND DESCRIPTION OF PROTECTIVE DEVICES

RESPIRATORY PROTECTION

A respirator is used to protect the respiratory system from harmful airborne contaminants that are not removed by engineering means. Respiratory protection devices function by removal of the contaminant from the air before it is inhaled or by supplying the user with an independent source of respirable air. An atmosphere is classified as hazardous if it contains toxic or disease producing gas, vapor or particulate material, or if it is deficient in oxygen, containing less than 19.5% by volume.

Respirator selection is based upon the hazard from which it must protect, and the environment in which it will be used. Some considerations in selecting a type of respirator include the nature of the operation, the concentration of the contaminant, the concentration of oxygen in the atmosphere, the physical characteristics of the contaminant, its permissible exposure limit, its physiological effects on the body, the health of the employee, and the length of time that the device must be worn. The three basic types of respirators will be described in greater detail. The various types of respirators are pictured in Exhibit 1-1.

Air-Purifying Respirators

Air-purifying respirators function by removing the contaminant. Since they do not supply oxygen, they may not be used in an atmosphere containing oxygen at less than 19.5% by volume. These respirators may be classified as particulate removing, vapor and gas removing, or combination particulate removing and gas and vapor removing.

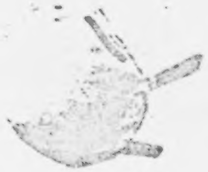
The means of purification may be mechanical filtration, adsorption, absorption, chemical reaction or catalysis. The life of the respirator depends upon such factors as the concentration of the contaminants, the breathing demand of the wearer and the removal capacity of the air-purifying medium. Filters are attached to the facepiece which is either quarter-face, half-face or full-face design.

1. Particulate Removing

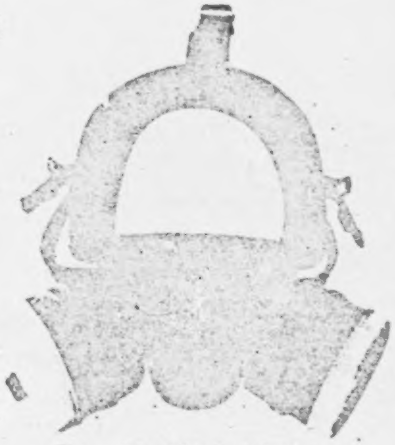
Particulate removing respirators function by means of mechanical filtration with particulate material such as dusts, mists, metal fumes and smoke being removed before

EXHIBIT 1-1
Respiratory Protection Devices

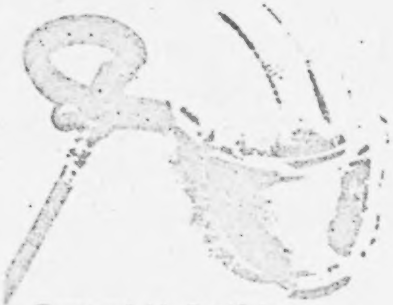
Abrasive Blasting
Helmet by 3M



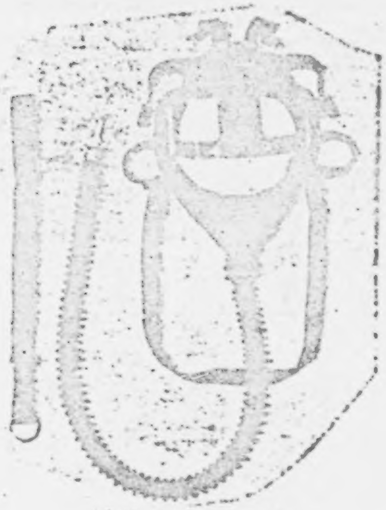
Disposable
Respirator
by 3M



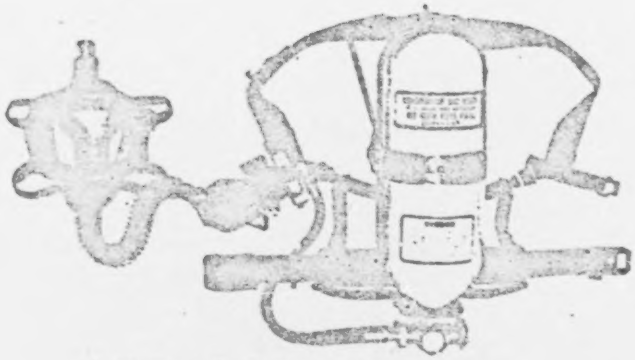
Reusable Air-Purifying
Respirator by Cesco



Powered Air Purifying
Helmet by Racal



Airline Respirator
by Willson



Self-Contained Breathing
Apparatus by Globe

they can be inhaled. The fibrous material in the filter removes the particles by interception, inertia causing impaction, diffusion through Brownian motion and electrostatic attraction. Approved respirators are usually over 95% efficient. The dust filters which are used for protection against pneumoconiosis producing and fibrosis-producing dusts are less efficient (80-90% against .8 µm particles) enabling the filter to withstand heavy dust loadings without increasing the breathing resistance to an unacceptable level. Particulate removing respirators become more efficient as matter collects on them and plugs the filter spaces.

The two primary types of dust filters are a flat disk to which is imparted an electrostati charge and a loosely packed filter medium such as fiberglass. In addition to particulate removing respirators with a replaceable or reusable filter, there exist single-use respirators and disposable respirators and powered air purifying respirators.

With the powered air purifying respirator, a blower is used to pass contaminated air through the element that removes the contaminant. Since it supplies air at a positive pressure, any leakage will occur outward from the facepiece even if the respirator fit is poor. Because of constant air flow through the air purifying element, the useful life of the cartridge is shorter. The device may be incorporated into a facepiece, helmet or hood.

2. Vapor and Gas Removing

Vapor and gas removing respirators have cartridges and canisters designed for protection against specific contaminants. The contaminant is removed by interaction with the sorbent, which is a granular, porous material. Removal may occur by adsorption, chemisorption and absorption.

Adsorption involves the physical attraction of the contaminant molecule which weakly bonds the contaminant and the sorbent. With chemisorption, the bond strength between the contaminant molecule and the sorbent is increased through chemical forces.

Adsorbents used in vapor and gas removing respirators include:

- activated charcoal impregnated with iodine to remove mercury vapor, metallic oxides to remove acid gases, or salts of metals to remove ammonia gases

- molecular sieves
- activated alumina
- silica gel

Compared with adsorbents, absorbents have a smaller surface area and the vapor and gas molecules penetrate more deeply and are held there chemically. Absorbents include mixtures of sodium or potassium hydroxide with lime or caustic silicates. Unlike adsorption, which occurs instantaneously, absorption happens slowly. Catalysts, such as hopcalite, are employed to increase the rate of chemical reaction between the contaminant and the sorbent.

One hundred percent (100%) efficiency is maintained until the sorbent's capacity to retain gas and vapor is exhausted. For this reason, the respirators should only be used against gases having a detectable odor or irritating effect, since at this point the contaminant will pass through the sorbent material and into the facepiece.

Cartridges and canisters differ in the volume of sorbent contained. Cartridges have a shorter lifespan with a sorbent volume of only 50-200 cm^3 and are usually restricted to use in low concentrations of vapors and gases.

Canisters have a larger sorbent volume with the size varying with the type of canister. The chin style canisters, which are used on full-face piece respirators, have a sorptive volume of 250-500 cm^3. Front or back mounted canisters or gas masks have a sorptive volume of 1000-2000 cm^3 and are used in higher concentrations of toxic contaminants or for prolonged use in lower concentrations of gas. The characteristics of gas masks and their canisters are shown in Exhibit 1-2.

3. Combination Particulate Removing and Gas and Vapor Removing

Cartridges and canisters are also available for use against a combination of particulates, vapors, and gases. The Type N canister resembles the front or back mounted canisters but internally it contains several different sorbents for various gases and vapors, a fibrous filter for particulates, and a catalyst for the conversion of carbon monoxide. Although the Type N canister has more sorbent layers, the layers are smaller. It has an indicator that shows when the carbon monoxide sorbent is exhausted.

EXHIBIT 1-2

Characteristics of Gas Masks and Their Canisters

Mask	Type	Max. Con. Of Gas (% by vol.)*	Color Of Canister (OSHA-NIOSH)*	Materials In Canister	Remarks
ACID GAS (for protection against gases such as hydrogen sulfide, sulfur dioxide, chlorine, hydrocyanic acid)	A	2%	White	Soda lime or soda lime and activated charcoal	The time of protection decreases rapidly as the concentration of gas increases. (See Notes 1,2,3,5)
ORGANIC VAPOR (for protection against vapors such as aniline, benzene, ether, gasoline, carbon tetrachloride, chloropicrin)	B	2%	Black	Activated Charcoal	(See Notes 1,2,3,5)
AMMONIA GAS	C	3%	Green	Silica gel or porous granules impregnated with metallic salts such as those of copper or cobalt	(See Note 4)
CARBON MONOXIDE	D	2%	Blue	Hopcalite	The air becomes noticeably warmer as the percentage of carbon monoxide increases(See Notes 1,2,3)
DUST FUMES, MISTS, FOGS & SMOKES in combination with any of the above gases or vapors	AE, etc.	2%	Any of above, plus top grey stripe	Any of above plus mechanical filter	(See Note 6)
COMBINATION ACID GAS AND ORGANIC GASES	AB	2% acid gases 2% organic vapors	Yellow	Activated charcoal and soda lime	See Notes 1,2,3,4)
COMBINATION ACID GAS, ORGANIC VAPOR & AMMONIA GAS	ABC	2% acid gases 2% organic vapor 2% ammonia	Brown	Soda lime, activated charcoal & silica gel or impregnated porous granules	As the number of gases increases, the service time of the canister decreases (See Notes 1,2,3)
COMBINATION ACID GAS, AMMONIA GAS	AC	2% acid gases 3% ammonia	Green with white stripe at bottom	Soda lime, silica gel or porous granules impregnated with metal salts such as those of copper or cobalt	
UNIVERSAL (for protection against combinations of acid gases, organic vapors, ammonia carbon monoxide and smokes)	N	Not exceeding 2% gases 3% ammonia 2% carbon monoxide 2% organic vapors Not more than 3% total poisonous gases	Red	Soda lime, activated charcoal, fused calcium chloride, silica gel or impregnated porous granules hopcalite, and filter	(See Note 3) Stripes to indicate filters are necessary on this type canister

Note 1: These gas masks are provided with a body harness to support the weight of the canister.

Note 2: These gas masks have check valves and exhalation valves.

Note 3: No gas mask will provide protection where the atmosphere is deficient in oxygen.

Note 4: If a dust, smoke or mist filter is combined with a gas filter, with the exception of the type N canister, it is shown by ½ inch black or white stripe on the canister.

Note 5: Canisters for a single gas or vapor other than ammonia or carbon monoxide shall have a ½ inch colored stripe around the canister near the bottom. The stripe for hydrocyanic acid gas is green, for chlorine, it is yellow.

Note 6: Canisters with additional filters for dusts, fumes, mists, etc. shall have a ½ inch contrasting black or white stripe around the canister located near its top.

* These are high concentrations. In the case of acid gases and ammonia, they are as much as can be tolerated because of discomfort from skin irritation.

* The 1973 revision of ANSI K13.1, Identification of Air-Purifying Respirator Canisters and Cartridges, changes some of the identifying colors. Be sure to check latest OSHA-NIOSH standards.

Reproduced from
best available copy.

Source: Accident Prevention Manual for Industrial Operations, National Safety Council, p. 493

Atmosphere Supplying

Atmosphere supplying respirators are classified as supplied air, self-contained breathing apparatus or combination supplied air and self contained breathing apparatus.

1. Self-contained Breathing Apparatus (SCBA)

The SCBA device consists of a full-facepiece which is connected to a wearer-carried source of oxygen or air, which holds up to four hours worth. Since the system admits no outside air, the units may be used in emergency situations in an oxygen deficient environment, and in situations where a high concentration of contaminants exist.

With the closed circuit SCBA, air is rebreathed after the carbon dioxide has been removed from the exhalants and oxygen is restored. The source of oxygen may be a wearer-carried oxygen cylinder or an oxygen generating solid. The oxygen from the cylinder is efficiently reduced by a reducing regulator to a breathing level before it is mixed with purified air. The wearer carried cylinder is bulky and the possibility of leakage exists due to the negative pressure which is created in the facepiece during inhalation. The unit, which employs an oxygen generating solid, usually potassium superoxide, is lighter and less expensive than the wearer carried cylinder unit but one disadvantage is that when the oxygen generating device is activated it cannot be turned off and the unit is only useful for about one hour.

The open circuit SCBA has a high pressure cylinder of air or oxygen, a full facepiece with an exhalation valve, regulators and a harness assembly. Exhaled air is not recirculated back to the user, but is exhausted into the atmosphere. Depending on the size of the tank of compressed air, the air supply may last from 5 to 30 minutes.

Air is delivered from the tank of compressed air to a two-stage regulator where pressure is reduced and then to the facepiece. The open circuit SCBA supplies the total breathing requirements, not only oxygen. The pressure-demand type of open circuit SCBA allows continual flow of air into the faceplece. Positive pressure is maintained within the facepiece at all times with any leakage occurring outwards. In the demand type of open circuit SCBA, air enters the facepiece on demand as inhalation creates a negative pressure in the facepiece causing the admission valve to open. The demand type has nearly the same negative pressure within the facepiece as an air-purifying device and should not be used in atmospheres immediately hazardous to life or health but may be used in oxygen deficient atmospheres. The pressure-demand SCBA provides the greatest protection and should be selected for emergency situations. Despite its continuous flow characteristics, the service time of the pressure-demand is nearly equal to the demand SCBA, providing that the proper facepiece seal exists.

2. Supplied Air

With supplied air respirators, air is delivered through a high pressure supply hose which is connected to a compressed air source located in a clean air environment and monitored for carbon monoxide. The devices are available with quarter mask, half mask, full facepiece, hood, helmet, or suit.

There are two types of supplied air respirators: air line and hose mask. Airline respirators include demand, pressure demand, and continuous flow devices. Without an ingress or egress cylinder, the respirators may not be worn in atmospheres that are harmful to life or health. The pressure demand airline respirator has continuous positive pressure in the facepiece and is used when inward leakage of the contaminant must be avoided. With the continuous flow airline respirator, constant air flow is achieved with the air flow control valve instead of a regulator.

The hose mask has a full facepiece with a hose connected to an uncontaminated air source. Air is delivered by means of a blower or with normal breathing. The hose length should be no longer than 50-80 meters when a blower is used and 15 meters without a blower. The hose mask with a blower may be used in atmospheres immediately dangerous to life or health.

In addition, abrasive blasting respirators are available for abrasive blasting work in a hood or helmet model. The air supplied hood, which is a similar device, is fabricated of a lighter material. Entire body protection from exposure to highly toxic substances is achieved with the air supplied suit. The air supply is used for breathing purposes and for isolating the entire body from the surrounding atmosphere.

HEAD PROTECTION

Protective headwear is used to protect the worker from solid objects, acids, hot liquids and electrical shock from overhead sources. Safety hats have a full brim encircling the hat. Safety caps have only a frontal brim. The headgear's suspension is the internal part of the hat consisting of sweat band and crown straps. The safety hat and safety cap are shown in Exhibit 1-3.

EXHIBIT 1-3

Protective Headwear

The shells of hard hats are fabricated of materials such as laminated phenolic resin, fiberglass impregnated with polyester resin, aluminum alloy, plastics containing phosphorescent pigments, polyethylene and thermoplastic materials.

Protective headwear is classified under one of four classifications:

- Class A hard hats have limited voltage protection and are slow burning.
- Class B hard hats are designed for electrical workers. The headwear has no metal parts, is slow burning and provides high voltage protection.
- Class C hard hats offer no electrical resistance or flammability protection.
- Class D hard hats are designed for fire fighters, have limited voltage protection and are made of self-extinguishing materials.

Bump caps are worn when the dangers of concussion or electrical accidents are not present.

FACE PROTECTION

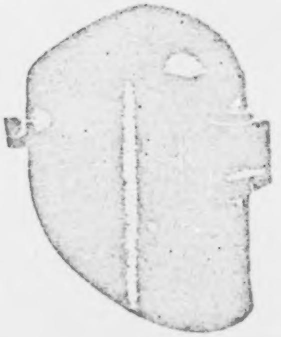
Face protection is employed to protect the worker from molten metal splash, sparks, chemical splash, flying metal chips, intense heat, and ultraviolet light. This type of protective equipment may be attached to protective headgear or worn separately. In addition, hand held models are available.

Faceshields are curved shields covering the worker's face and may be fabricated from many types of material, primarily heat resistant plastic. Faceshields are categorized as chemical splash, impact (polycarbonate), molten metal (wire mesh screen), and welding and cutting (heavy-duty fiberglass w/lens). Flared sides are incorporated to deflect hazards away from the side of the head and neck. Aluminized plastic devices are coated to reflect radiant heat. Special lenses on welder's shields provide greater protection from intense light. Clear shields are tinted to reflect glare.

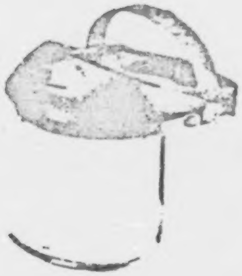
Welder's helmets including welder's hand held shields must not be readily flammable and must protect the face from direct radiant heat. The devices must have easily removable filter plates. Examples of face protection are provided in Exhibit 1-4.

EXHIBIT 1-4

Face Protection Devices



Welding Helmet



Face Shield

Source: Jackson Products

HAND PROTECTION

Selection of glove materials is determined by the hazard from which the worker must be protected. These workplace hazards include heat, flame, sparks, electricity, radiation, chemicals, abrasion and puncture. Various types of gloves are shown in Exhibit 1-5.

The materials that are selected to protect against specific hazards include:

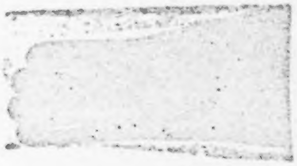
Heat	Asbestos
	Asbestos and Leather
	Leather
	Glass Fiber
	Aluminum Fiber
	Aluminum Asbestos
	Other Asbestos Substitutes
Flames	Asbestos
	Leather
	Glass Fiber
	Aluminum Fiber
	Duck
Sparks	Asbestos
	Asbestos and Leather
	Leather
	Glass Fiber
	Duck
Chemicals	Natural Rubber
	Synthetic Rubber
	Plastic
	Plastic-coated Glass Fabric
	Synthetic Fabric

EXHIBIT 1-5

Hand Protection

Leather

Fabric



Leather Welder's

Neoprene Unsupported

Vinyl Coated

Neoprene Coated

Source: Magid Glove

Cutting or Puncture	Leather or Steel Mesh Metal Mesh Metal or Molded Plastic
Abrasion	Glass Fiber Coated Fabric Fabric
Radiation	Leaded Rubber Leaded Leather Leaded Plastic
Electrical	Leather Over Rubber

Other factors which must be considered when selecting the proper glove include the use of heat exposure (reflective or direct); the material to be handled (wet or dry), the average time of handling, the necessity of splash or seepage protection, the needed degree of dexterity, and the cost to wear ratio.

The lining materials of gloves most frequently worn are flannel, jersey knit, interlock knit and thermal. The lining is incorporated to increase the longevity of the glove, resist snags and punctures, reduce skin abrasion and soak up perspiration.

The more commonly used glove coatings are rubber, PVC and other plastics, and vinyl or metal impregnated. Coated gloves have better moisture, chemical, and solvent resistance.

The degree of protection provided by different types of gloves against certain chemicals is shown in Exhibit 1-6.

EXHIBIT 1-6

Protection Against Workplace Chemicals by Certain Glove Materials

Plastic Coating

Excellent

- Acetic Acid, 30%
- Acetic Anhydride
- Acetone
- Air
- Ammonia, 100%
- Ammonium Hydroxide
- Amyl Acetates, Mixed
- Amyl Alcohol
- Benzine Sulfonic Acid, 10%
- Benzoic Acid
- Butyl Alcohol
- Calcium Hydroxide
- Carbonic Acid
- Chloroacetone
- Chromic Acid
- Citric Acid, 10%
- Cocoanut Oil
- Cottonseed Oil
- Ethyl Acetone
- Ethyl Alcohol
- Ethyl Benzene
- Ethylene Glycol
- Gasoline
- Formic Acid, 30%
- Glycerine
- Hydrobromic Acid, 40%
- Hydrochloric Acid, 30%
- Hydrofluoric Acid, 30%
- Lactic Acid
- Lanolin
- Lard
- Linseed Oil
- Maleic Acid
- Mineral Oil
- Naptha
- Neats Foot
- Nitric Acid, 12%
- Octyl Alcohol
- Olive Oil
- Oxalic Acid
- Palm Oil
- Perchloric Acid, 2½%
- Phosphoric Acid, Conc.
- Plating Solutions
- Salts
- Sodium Hydroxide, Conc.
- Sulfur Dioxide
- Synthetic Oil
- Tallow
- Tannic Acid, 10%
- Tartaric Acid
- Tertiarty Butyl Alcohol
- Trichloroacetic Acid, 10%
- Water

Good

- Acetophenone
- Benzene
- Benzyl Alcohol
- Butane
- Butyl Acetate
- Carbon Tetrachloride
- Chlorine
- Dibutyl Phthalate
- Dioctyl Phthalate
- Ethyl Acetate
- Ethyl Benzoate
- Heptane
- Hexane
- Kerosene
- Octane
- Propane
- Propyl Alcohol
- Sulfuric Acid Conc., Cold
- Sulfurous Acid, 6%
- Toluene
- Tricresyl Phosphate
- Turpentine
- Xylene

EXHIBIT 1-6 (Continued)

Fair

Stoddard Solvent

Poor

Amylacetate
Cyclohexane

Methyl-ethyl-ketone
Methyl-isobutyl-ketone

Sulfuric, Conc, Hot

Neoprene Latex

Excellent

Amyl Alochel
Benzene Sulfonic Acid, 10%
Butane
Butyl Alcohol
Carbonic Acid
Citric Acid, 10%
Cocoanut Oil
Cold Water
Ethyl Alcohol
Ethylene Glycol

Glycerine
Heptane
Hydrobromic Acid, 40%
Hydrochloric Acid, 30%
Hydrofluoric Acid, 30%
Kerosene
Maleic Acid
Octyl Alcohol
Oxalic Acid

Perchloric Acid, 2½%
Phosphoric Acid, Conc.
Plating Solutions
Propane
Salts
Sulfuric Acid, Conc. Cold
Sulfurous Acid, 6%
Tartaric Acid
Tertiary Butyl Alcohol

Good

Acetic Acid, 30%
Acetic Anhydride Acid
Acetone
Acetophenone
Air
Ammonia, 100%
Ammonia Hydroxide, Conc.
Benzoic Acid
Benzyl Alcohol
Butyl Acetate
Cottonseed Oil
Chloracetone
Ethyl Benzene

Ethyl Acetate
Formic Acid, 30%
Gasoline
Hexane
Hot Water
Lactic Acid
Lanoline
Lard
Linseed Oil
Mineral Oil
Naphtha
Neats Foot

Octane
Olive Oil
Palm Oil
Propyl Alcohol
Sodium Hydroxide, Conc.
Synthetic Oil
Stoddard Solvent
Sulfur Dioxide
Tallow
Tannic Acid, 10%
Trichloroacetic Acid
Turpentine

EXHIBIT 1-6 (Continued)

Poor

Amyl Acetate
Amyl Acetate, Mixed
Benzine
Calcium Hydroxide, Conc.
Carbon Tetrachloride
Chlorine
Chromic Acid
Cyclohexane
Dibutyl Phthalate
Dioctyl Phthalate
Ethyl Acetone
Ethyl Benzoate
Methyl-ethyl-ketone
Methyl-isobutyl-ketone
Nitric Acid, 12%
Sulfuric Acid, Conc, Hot
Toluene
Tricresyl Phosphate
Xylene

Rubber

Excellent

Ammonia, 100%
Amyl Alcohol
Benzoic Acid
Butyl Alcohol
Chromic Acid
Chlorine
Citric Acid, 10%
Cold Air
Ethyl Alcohol
Ethylene Glycol
Glycerine
Hydrobromic Acid, 40%
Hydrochloric Acid, 30%
Hydrofluoric Acid, 30%
Maleic Acid
Octyl Acid
Oxalic Acid
Perchloric Acid, 2½%
Phosphoric Acid, Conc.
Plating Solution
Propyl Alcohol
Salts
Sulfur Dioxide
Sulfuric Acid, Conc.
Tartaric Acid
Tertiary Butyl
Water

Good

Ammonia Hydroxide, Conc.
Benzyl Alcohol
Calcium Hydroxide, Conc.
Carbonic Acid
Sodium Hydroxide, Conc.
Sulfurous Acid, 6%
Tannic Acid, 10%

Poor

Acetic Acid, 30%
Acetic Anhydride
Acetone
Acetophenone
Amyl Acetate
Amyl Acetates, Mixed
Dioctyl Phthalate
Ethyl Benzene
Ethyl Acetate
Ethyl Acetone
Ethyl Benzoate
Mineral Oil
Naphtha
Neats Foot
Nitric Acid, 12%
Octane
Olive Oil

EXHIBIT 1-6 (Continued)

Benzene
Benzene Sulfonic, 10%
Butane
Butyl Acetate
Carbon Tetrachloride
Chloracetone
Coconut Oil
Cottonseed Oil
Cyclohexane
Dibutyl Phthalate
Formic Acid, 30%
Gasoline
Heptane
Hexane
Hot Air
Kerosene
Lactic Acid
Lanoline
Lard
Linseed
Methyl-ethyl-ketone
Methy-isobutyl-ketone
Palm Oil
Propane
Stoddard Solvent
Synthetic Oil
Tallow
Toluene
Trichloroacitic Acid
Tricresyl Phosphate
Turpentine
Xylene

The different types of glove materials are summarised as follows:

Asbestos and Aluminized	- Protect against burns from hot objects
Metal Mesh	- Protect against knives and other sharp objects
Natural Rubber	- Smooth finish for chemical resistance - Crinkle finish for wet/drip gripping
Neoprene Rubber	- Resistance to chemical solvents and oils
Nitrile Rubber	- Resistance to abrasion cuts, and punctures
Natural or Synthetic Latex	- Chemical resistant
Leather	- For heavy duty work and for resistance to sparks, chips, heat and abrasion
Fabric	- For medium duty work and for resistance to dirt, abrasion and chafing
Leaded	Handling radioactive substances

New developments in glove materials include Zetex by Nutex and Kevlar by DuPont along with other new heat resistant fabrics. Kevlar, aramid fiber, may be used for limited contact at temperatures as high as 1000°F with charring beginning at 800°F. Zetex, which is made from fiberglass, is used at temperatures of 1000°F and higher.

Hyd-Tuf, a NBR coated glove by Edmont, is viewed as a replacement for leather and is used in such industries as construction and shipping. Viton, a fluoroelastomer from DuPont, was the only glove material in a NIOSH study that was not easily permeated by solvents. The glove costs more than ten times the amount of the other gloves studied. It also withstood permeation by PCBs for up to one hour.

PROTECTIVE FOOTWEAR

Protective footwear is necessary to protect the foot from injury by heavy objects, from objects penetrating the sole, or by striking against objects. Other hazards exist such as corrosive chemicals, electricity, sparks, molten metal and slippery surfaces. The footwear is employed as protection against pipe, barrels, and other rolling objects, truck wheels and sharp metal. Compression injuries may be eliminated or lessened with the use of metal safety-toe caps or metal footguards.

Protective footwear is classified as (1) safety toe, (2) metatarsal safety toe, (3) conductive safety-toe, (4) non-sparking, (5) electrical hazard safety-toe, and (6) foundry shoes.

Protective footwear is fabricated of leather, rubber or plastic. Metal guards to protect the metatarsal, the toes and/or the legs are manufactured of aluminum, steel, fiber or plastic. Toe boxes with a wide flange or lip are used to increase the protection afforded by steel toe safety shoes. With a narrow flange, sufficient area between the inner sole and the toe box is not provided causing reduced clearance between the toe box and the toe from the safety toe cutting into the sole. This problem is also preventable with the use of stronger sole materials. Improvements in safety toes are being instituted with the quality of steel toes being upgraded and puncture resistant soles being featured.

Conductive shoes (Type I) have an electrical resistance between 25,000 and 500,000 to protect against static electricity in areas where explosions are possible. Type II conductive shoes have an electrical resistance of 10,000 ohms or less to protect the worker exposed to high voltage lines by equalizing the potential of the wearer and the energized parts to which he is exposed. A conductive snap connector around the lower leg is connected to the back of the Type II shoe to make a path for electricity through the heel and sole. Conductive shoes have a non-ferrous external construction to avoid friction sparks and have heels of conductive rubber.

Linemen, electricians and maintenance personnel wear electrical-hazard shoes as an insulating medium between the wearer and the ground. The shoes have electrically insulating rubber soles and provide protection against open circuits of up to 600 volts. Explosives operations or nonsparking shoes are worn in areas containing potentially explosive materials. Metal parts are either omitted from the shoes or metalized with a non-ferrous metal. Foundry shoes are designed for quick removal when sparks, hot cinders, glass, molten metal or splash enters the top of the shoe.

The trend in shoe design appears to be toward lighter weight and more stylish footwear including oblique toe shoes, western styled safety boots, steel toed casual and joggers, and styles for women workers. Protective footwear is depicted in Exhibit 1-7.

EXHIBIT 1-7

Protective Footwear

PROTECTIVE CLOTHING

Clothing Materials

Selection of protective clothing is based on a number of factors, e.g. comfort, appearance, reuse, durability, water and splash repellancy, flame retardancy and flame resistance, and resistance to soil and hazardous materials. The material is judged on its breathability, lightweight, ease of moisture transmission, launderability, and resistance to water-based and oil-based stains, abrasion, dirt, and splash.

Protective clothing is often identified by the brand name of material from which it is fabricated. Gore-Tex is a microporous membrane of pure polytetrafluoroethylene (PTFE) that is laminated between two layers of fabric, polyester oxford on the outer layer and polyester tricot on the inner layer. It resists liquid chemical penetration while providing excellent breathability and allowing moisture vapor to evaporate. Because of its breathability, it is selected for use by firefighters. The material is manufactured by W.L. Gore.

Tyvek by DuPont is a spun-bonded olefin which is non-woven material of polyethylene fibers used in disposable clothing. The clothing is used in clean rooms, nuclear sites, shipyards, the military, printing, painting and other industries, and with exposure to PCBs, asbestos, pesticides, acids, caustics, and solvents.

Kaycell by Kimberly-Clark is nylon reinforced paper made by bonding layers of cotton-like cellulose fibers to nylon. The material is fire and water resistant and is used in disposable clothing.

Saranex by Dow can withstand PCBs up to one hour before penetration begins. It can be laminated with other materials, such as Tyvek, to provide greater protection. The laminants protect against cresols, ortho-toluidine, sodium dichromate, 1,2,4-trichlorobenzene, 98% sulfuric acid, and 40% sodium hydroxide.

DuPont's Nomex is an aramid fiber that is flame and temperature resistant, up to 700°F and resists acids and water. It provides better resistance than cotton, polyester cotton, or flame retardant cotton. Despite its greater cost, it will outwear polyester cotton. In a flash fire, Nomex becomes charred, causing a carbon crust that provides a protective barrier.

Nor-fab by Amatex consists of aramid and semi-carbon stabilized fibers. The material is flame and heat resistant up to 650°F and is durable, flexible, abrasion resistant and has high seam strength.

Nutex's Zetex is a fiberglass material with greater comfort, better thermal insulating properties and five times the strength of asbestos. It withstands temperatures close to 1100°F, cold to -100°F, and resists most acids, alkalies and solvents. The material may be coated with SBR, NBR, Hypalon or Viton.

DuPont's Kevlar 29, an aramid fiber, is cut resistant and heat resistant below 1000°F. Ballistic Kevlar is used in helmet and bullet-proof vests. It may be used in temperatures over 1000°F.

DuPont's Sontara FR is a disposable spunlaced material that outwears cellulosic nonwoven garments. It is flame and abrasion resistant.

Preox by Gentex is more comfortable, more flexible, has one-third the weight, twice the radiant heat protection, and is stronger than asbestos. It also performed better in the molten splash test.

Disposable Clothing

Disposable clothing is used primarily in the medical, chemical, mining, machine manufacturing, primary metal, and metal fabrication industries. The clothing is selected for its resistance to water, static, heat, chemicals and radioactivity. It may be discarded after one use or reused on a limited basis. The clothing is fabricated of Tyvek, coated Tyvek, polypropylene, plastics-coated cellulose or lightweight plastics.

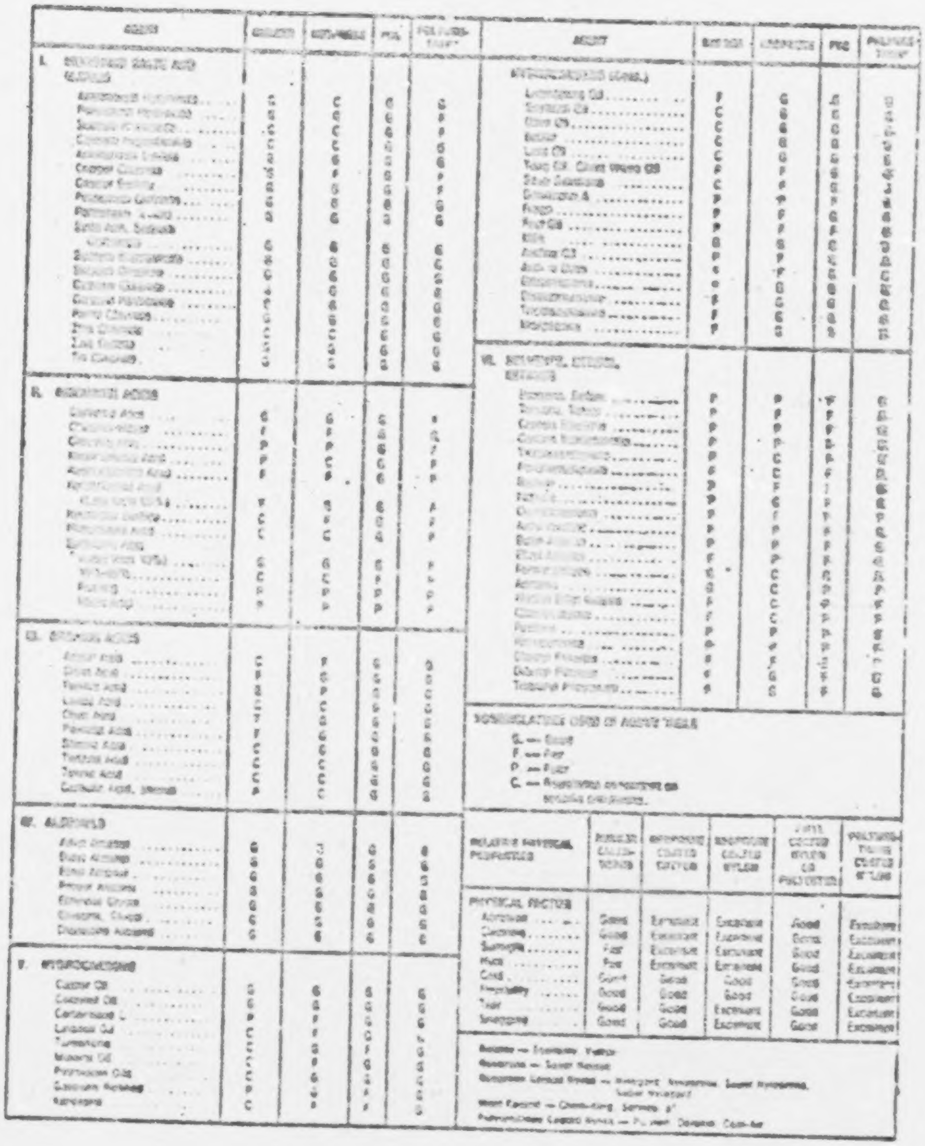
Rainwear and Chemical Resistant Clothing

Protective hoods, trousers, coveralls, jackets and suits are worn by maintenance workers, building and civil engineering workers or other outdoor workers to protect against inclimate weather.

Chemical resistant clothing is needed in chemical and pharmaceutical companies, refineries, laboratories, acid cleaning processes, safety, maintenance and fire rescue. The clothing will impede the penetration of hazardous substances to permit removal of the clothing by the worker. Exhibit 1-8 shows the degree of protection afforded by different materials.

EXHIBIT 1-8

Materials Resistance Chart



Source: Rai..Mair, Inc.

Air supplied suits have been previously discussed under respirators. The completely enclosed suits provide protection from bacteria, chemical, radiation, etc. Acid-proof suits protect from exposure to acid vapors or splashes. The suits are made from material such as cotton polyester and a coated elastomer. Gas-proof suits may be pressurized or non-pressurized. The suit may be made of a woven polyester coated with butyl rubber, aluminized neoprene, styrene-butadiene rubber, and chlorosulphonated polyethylene.

Heat Resistant Clothing

Asbestos is a heat resistant fabric which protects from radiant heat, hot metal and flames at temperatures as high as 3000°F with special treatment. Concerns about the health hazards of asbestos have led to the development of asbestos substitutes.

Aluminized clothing is used in foundries slagging, firefighting and rescue work in temperatures up to 2000°F. The clothing reflects the heat and insulates against it. Emergency suits are fabricated of aluminized asbestos or glass fiber with an inner layer of glass or wool. The suits are used in temperatures greater than 1000°F in kilns or furnaces. Fire proximity suits have a certain degree of reflectivity but are not used for entry into fires.

Leather clothing is used for protection against heat and molten metal splash.

HEARING PROTECTION

Hearing protection protects the worker from hearing loss, provides a quieter workplace, and ensures compliance with OSHA regulations when noise levels cannot be reduced. The OSHA hearing conservation amendment became effective on August 22, 1981. With the exception of the agriculture and construction industries, the rule requires hearing conservation practices for workers exposed to noise levels equal to or exceeding 85 decibels for an eight-hour time weighted average which include hearing protection, exposure monitoring, audiometric testing, and employee training. Hearing protection is required when exposure is equal to or greater than 90 dB TWA or 85 dB TWA for persons with a hearing loss Hearing protection must be available for all employees exposed to noise levels above 85 dB (TWA).

Ear plugs fit into the outer portion of the ear canal and protect against high frequency noise. The plugs may be manufactured of silicone rubber, PVC, polymer foam, waxed cotton, or mineral fibers. Earmuffs are more desirable than plugs when noise levels are 105 dBA or greater. They are made of light metal or plastics containing sound absorbent materials and have a lining that acts as a seal. Communication devices resemble muffs but have a means of transmitting communication or music.

Hearing protectors have noise reduction ratings describing their effectiveness for the purposes of comparison. Earmuffs are normally 15-25 dBA, premolded and custom molded plugs are 10-25 dBA, and disposable plugs are around 20 with some foam plugs reaching 29.

Various types of hearing devices are depicted in Exhibit 1-9.

PROTECTIVE EYEWEAR

Protective eyewear includes safety glasses, goggles, sideshields and visitor's eyewear. Safety glasses are classified as pleno or prescription heat-treated. They incorporate lenses of glass, polycarbonate or alkyl diglycol carbonate (CR-39) and must pass impact testing standards. Glass lenses offer good abrasion resistance and may provide resistance to ultraviolet and infrared rays. Plastic lenses are lighter in weight and provide greater impact strength but are less resistant to scratching. These lenses offer pitting resistance to welding spatter and may be formulated to absorb ultraviolet radiation but not infrared radiation. Protection against particles entering from the side may be provided with sideshields, usually manufactured of plastic or mesh.

Goggles protect from a variety of hazards depending on the type selected. Protection against severe impact in chipping and grinding, chemical splash, and ultraviolet and infrared radiation. Goggles are decribed as flexible vinyl or rigid body rubber mask, chemical splash, cup, welders, or chippers. Visitor's eyewear are molded from cellulose propionate.

Examples of protective eyewear are shown in Exhibit 1-10.

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EXHIBIT 1-9

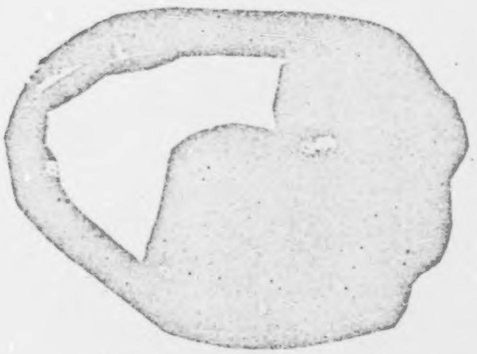
Various Types of Ear Plugs

Disposable Plugs by EAR

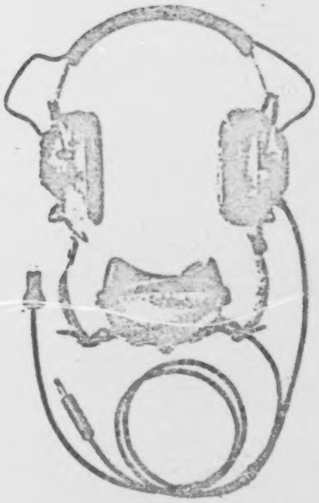
Disposable plugs
by Bilsom

Reusable Plugs by American Optical

Band by Willson



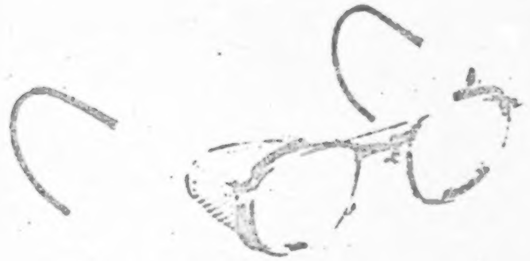
Earmuffs by Bilsom



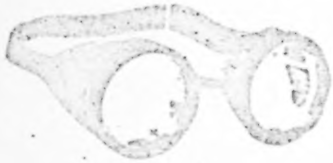
Communication Device
by Willson

EXHIBIT 1-10

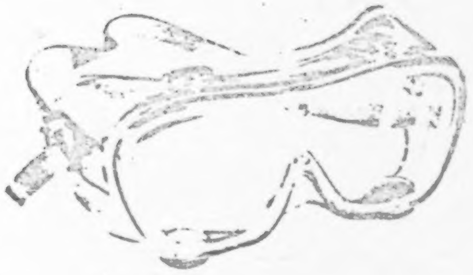
Protective Eyewear



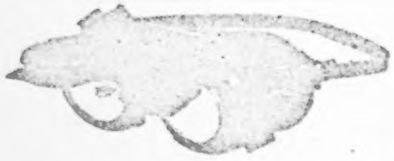
Safety Glasses with Sideshields



Cup Goggle



Chemical Splash Goggle



Welder's Goggle

Source: U.S. Safety Service

SECTION II

SPECIFICATIONS FOR THE PERFORMANCE OF PROTECTIVE DEVICES

TESTING AND CERTIFICATION OF PERSONAL PROTECTIVE EQUIPMENT

Consensus standards were first established by safety directors in the early 1900's. In the 1960's critics claimed that the consensus standard groups did not have sufficient representation of labor and consumer groups. Companies represented in the consensus group could prevent competitors from receiving approval of their products. The Federal Government began testing of products for standards and for the protection of all users of these products.

When OSHA was established, the National Fire Protection Association (NFPA) and the American National Standards Institue (ANSI) were incorporated into the system to organize and expedite the system's formation. Standards were revised following review by private industry, federal agencies and the public.

ANSI establishes and coordinates voluntary consensus standards. These standards are developed, reviewed and revised by technical committees according to certain procedures. The National Institute for Occupational Safety and Health (NIOSH) tests, approves and certifies certain types of equipment. Manufacturers submit their products for testing by ANSI standards.

NIOSH announced in 1979 its intention to upgrade its testing and certification program because of the past history of poor performance of NIOSH certified equipment and certain needs such as systematic means of notification and recall, protocol for recertifying equipment and an information feedback system. Suggested alternatives included continued joint testing and certification of respirators with the Mine Safety and Health Administration, having NIOSH test and certify respirators, having NIOSH certify private laboratories to test and certify respirators under NIOSH performance standards, and having industry test and certify respirators under NIOSH performance standards. NIOSH favored a new testing and certification program that would allow NIOSH to be solely responsible for testing and certifying respirators.

The Industrial Safety Equiment Association (ISEA) had been advocating that NIOSH develop a testing and certification program for all personal protective equipment in addition to its current program for respirators. The Association favers the use of private laboratories to test and certify equipment and have NIOSH test the equipment at its own laboratory in the presence of a manufacturer's respresentative.

The Safety Equipment Institute was formed in July 1981 by the Industrial Safety Equipment Association to test and certify hard hats and eyewear and eventually all types of protective equipment. The specifics of the testing programs are provided in two manuals from ISEA, the Quality Assurance Manual and the Certification Program Manual.

TESTING STANDARDS

The specific testing standards for the various types of personal protective equipment are shown in Exhibit 2-1.

EXHIBIT 2-1

Testing Standards for Personal Protective Equipment

Type of Protection	Standard
Eye	ANSI Z87.1 - 1979
Face	ANSI Z87.1 - 1979
Respiratory	ANSI Z88.2 - 1980
Head	ANSI Z89.1 - 1981
Foot	ANSI Z41 - 1981
Hearing	ANSI Z137.1 (draft form)
Clothing	ASTM F-23 Committee Test Procedures being developed. F-739 is the only standard which has been issued to date.

Respiratory Protection

The ANSI Z88.2-1980 standard, "Practices For Respiratory Protection," revises the 1969 ANSI standard. The 1980 standard discusses such issues as quantitative fit testing, qualitative fit testing, protection factors, oxygen deficiency, higher protection factors used when quantitative fit testing is employed, and use in confined spaces. ANSI standard Z88.3 and Z88.5 addresses respiratory protection during fumigation and fire service respectively. ANSI Z88.1 Respiratory for Radon Daughters and Z88.4 Respiratory Protection for Coal Miners have been withdrawn

Eye Protection

ANSI standard Z87.1 is under slight revision and will be submitted to ANSI by June 1983. A revision of the ANSI standard, "Practice for Occupational and Educational Eye and Face Protection was issued in 1979. The ANSI Z2.1-1959 standard was updated in 1968 in the form of ANSI Z87.1-1968 which required greater impact resistance of the lenses in a frame and in welder's and cutter's goggles and more stringent disinfection requirements. Frames of metal and/or plastic must support the lenses, withstand fracture resistance testing and be slow burning. The lenses are at least 3.0 mm thick, heat treated and are tested by dropping a 1-inch steel ball from 50 inches.

The 1979 revision mandates that certain lenses such as plastic lenses employed in operations involving molten metal and variable-tint lenses used in outdoor jobs not involving ultraviolet and infrared radiation, also referred to as phototropic lens, be labeled with a "V" and have the manufacturer's identification on the lens. Glass filter plates must be labeled with an "H" for impact resistance. The standard also covers safety glasses without sideshields or with flat-fold sideshields and those with orbital fitting or full eyecups. The Z87 logo must be imprinted on the temples and frames of the eyewear.

In addition, the standard addresses such concerns as lenses for special purposes including lenses for glassblowing and for use around metal and glass furnaces, rigid cover goggles with a cushioned material which provides the necessary seal around the wearer's face, and goggles used for dust protection vs. goggles for splash protection. The term, front, is used to describe the part of the safety spectacle known as the frame. For protection against molten metal splash, plastic lenses are recommended. Tinted or absorptive lenses should not be worn indoors or when no hazard is present.

Face Protection

The revised standard requires the impact resistance testing of face shields. The window must completely cover the eye area from exposure. ANSI recommends that eye protection be worn along with the faceshield. Warnings for UV and infrared radiation must be displayed when transmittance is less than 40%. Changes in welding helmet requirements include an allowance for shell thickness of 1.2 mm for vulcanized fiber and 1.0 mm for other materials, and a provision requiring more impact resistance for safety plates than for filter plates and requiring 85% luminous transmission for cover plates.

Head Protection

ANSI Z89.1-1981 combines ANSI Z89.1-1969 for industrial head protection and Z89.2-1971 for protective helmets for electrical workers. Separate standards are being developed for fire fighters' helmets, Z89.3, but this process is "on hold" at the present time. The ANSI standards for the four classes of head protection are shown in Exhibit 2-2.

EXHIBIT 2-2

ANSI Standards for Head Protection

	INSULATION RESISTANCE	IMPACT RESISTANCE	PENETRATION RESISTANCE	WEIGHT	FLAMMABILITY	WATER ABSORPTION
ANSI REFERENCE	7.1	7.2	7.3	7.4	7.5	7.6
CLASS A	2,200 Volts AC, (60 Hz For 1 Minute With Leakage Current Not In Excess of 3 Milliamperes)	Transmits An Average Force of 850 Lbs.	Cannot Be Pierced More Than 3/8" (.95 cm)	Not To Exceed 15 oz. (425g)	3" (7.6 cm) Per Minute Burn Rate	5.0% Of Water
CLASS B	20,000 Volts AC, (60 Hz For 3 Minutes With Leakage Current Not in Excess of 9 Amperes.)		Cannot be Pierced More Than 3/8" (.95 cm)	Not To Exceed 15.5 oz. (439g)	3" (7.6 cm) Per Minute Burn Rate	0.5% Max.
CLASS C	No Voltage Protection		Cannot Be Pierced More Than 7/16" (1.58 cm)	Not To Exceed 15 oz. (425g)	No Flammability Protection	5.0% Of Water
CLASS D (Available only as Type-1-Hat)	2,200 Volts, AC, (60 Hz For 2 Minutes With Leakage Current Not In Excess Of 3 Milliamperes		Cannot Be Pierced More Than 3/8" (.95 cm)	Not To Exceed 30 oz. (850g)	Self-Extinguishing	

Source: Best's Safety Directory, 1980

Foot Protection

Public review of the ANSI footwear standards is being conducted with some changes included and each subsection has been incorporated into one standard, Z41. ANSI Standard Z41.1 for protective footwear was revised in 1981. The revised standard requires that women's safety shoes be tested using a size 8 medium and must provide for a minimum clearance of 15/32 inch for women's safety footwear. Required clearance for men's footwear is one-half inch. Previous requirements dictated that footwear subjected to 30, 50, or 75 ft.-lb. impact and an average compressive force of 1000, 1750 or 2500 lbs. could not have in the internal clearance of the toe box less than .318 inch for Class 30 and one-half inch for Class 75.

Previous testing requirements for impact strength involved the release of a 50-lb. weight (75 lb. for Class 75) onto a 1-inch diameter steel plunger with the lowest height of a clay cylinder being recorded to measure the maximum deflection of the toe box. The new standard changed the impact testing method by substituting velocity of the test weight instead of the height from which it is dropped to determine the amount of foot pounds to which the shoe has been subjected. The earlier standard required the reporting of impact and compression testing in a single rating, however, the revised standard allows for the separate reporting of impact and compression testing.

Footwear must identify the results of impact and compression testing. Compression testing is conducted using a machine which applies a load at 50 lb./sec. with a feeler gauge on the insole which moves under the toe box with the application of each load. Compression strength is the load at which the feeler gauge no longer moves. The standard requires compression resistance of 1000 lbs. for Class 30, 1750 lbs. for Class 50, and 2500 lbs. for Class 75.

ANSI standard Z41.2 applies to metal guards used to protect the metarsal, the toes and/or the legs.

Hearing Protection

An ANSI standard for hearing protection (ANSI Z137.1) has been proposed. The standard is presently in draft form and is entitled, "Personal Hearing Protection Devices for Use in Noise Environments."

Protective Clothing

Standards for protective clothing are being developed by the American Society for Testing and Materials (ASTM) including degradation, seam, and penetration testing. A standard for thermal properties for protective clothing is nearing completion. ASTM Standard F739, "Resistance of Protective Clothing Materials to Permeation for Hazard Liquid Chemicals," is the only standard that has actually been issued.

SECTION III

MANUFACTURERS OF PERSONAL PROTECTIVE DEVICES AND THEIR PRODUCT OFFERINGS

RESPIRATORY PROTECTION

The largest number of respirator manufacturers offer reusable air purifying respirators and supplied air respirators. A fewer number have a product line which includes disposable respirators, powered air purifying respirators or self-contained breathing apparatus.

Respirator manufacturers such as American Optical, Norton, MSA, Willson and U.S. Safety also offer a broad line of safety products. A listing of the suppliers of respiratory protection devices is shown in Exhibit 3-1.

New manufacturers who have entered the respiratory protection market include Bendix, National Draeger and International Safety Instruments, Inc. along with a smaller company, Neoterik. In addition, established manufacturers are expanding their product lines including Survivair, who now offers air-purifying respirators in addition to SCBA and supplied air respirators. Entry in the market is not necessarily a response to user dissatisfaction with current products, but because of greater usage of respiratory protection as a result of regulations, the expense of engineering controls.

HEARING PROTECTION

The major suppliers of hearing protection are EAR, division of Cabot Corporation, Bilsom, Norton, Willson Safety Products, David Clark Co., Flents Products, and Mine Safety Appliances. A more complete listing of hearing protection suppliers is provided in Exhibit 3-2. A number of these suppliers concentrate only in hearing protection. These companies include Bilsom, EAR, Earmark, Flents and Remie. Other companies such as American Optical, Apex, U.S. Safety, Glendale, Norton, 3M and Willson have a broader line of safety products.

Earmuffs are offered by more manufacturers than any other type of hearing protection. There are as many suppliers of reusable plugs as there are suppliers of disposable plugs.

SPRINGBORN MANAGEMENT SERVICES INC

EXHIBIT 3-1

Suppliers of Respiratory Protection

Supplied Air - Airline

American Optical
Bullard
CESCO - U.S. Safety
Encon
Glendale

Globe
MSA
Norton
Pulmosan
Racal

Robertshaw
Scott
Survivair
3M
Willson

Self-Contained Breathing Apparatus (SCBA)

Bendix
Econ
Globe
ISI

MSA
National Draeger
National Mine Service
Racal

Rexnord Safety Products
Robertshaw
Scott
Survivair

Powered Filter Respirator - Highly Toxic Atmospheres

MSA

Pulmosan

Racal

Powered Filter Respirator - Abrasive Blasting Applications

Apex
CESCO & U.S. Safety
Encon

Glendale
MSA
Pulmosan

3M
Willson

Air Purifying Helmet With Powered Air - Purifying Respirator

Racal

3M

Reusable Air Purifying Respirator With Filter, Cartridge or Canister

American Optical
Apex
H.S. Cover
CESCO & U.S. Safety
Glendale

MSA
National Draeger
Norton
Pulmosan

Scott
Sellstrom
Survivair
Willson

Disposable Respirator

American Optical
Glendale

Norton

3M

EXHIBIT 3-2

Suppliers of Hearing Protection

Muffs

American Optical
Apex
Bilsom
Bullard
CESCO and U.S. Safety
David Clark

Erb Safety
Fibre Metal
Flents
Glendale
Jackson Products
MSA

Norton
Pulmosan
Racal
Safety Direct
Tasco
Willson Safety Products

Communication Devices

Acoustic Instruments Int'l, Inc.
Bilsom
David Clark

Earmark
Quest
Romic

Telex Communications, Inc.
Willson

Plastic Earplugs (PVC)

American Optical
Apex
CESCO and U.S. Safety
Fibre Metal
Flents

French Laboratories
Glendale
Hocks Laboratories
Jackson-Adco
MSA

Safety Direct
Tasco
3M
Willson Safety Products

Silicone Rubber Earplugs

Adco
Bilsom
Flents

French Laboratories
Hocks Laboratory

MSA
Tasco

Fiber

Adco

Bilsom

Flents

Waxed Cotton

Adco

Flents

Soft Polymer/Self-Forming Foam

Adco
EAR

Erb Safety
Flents

Norton
Willson Safety Products

With the exception of Willson, the suppliers of PVC plugs repackage plugs made by Plasmed and one or two other companies. The same holds true for silicone rubber plugs with only MSA, Norton and Bilsom manufacturing their own plugs. EAR makes Norton's foam plug.

HEAD PROTECTION

The suppliers of hard hats number around twenty. Most supply ANSI Classes A, B, and C types, but only a few supply Class D. Mine Safety Appliances is the largest supplier of hard hats, followed by Bullard and Fibre Metal. The suppliers of hard hats and caps are shown in Exhibit 3-3.

EXHIBIT 3-3

Suppliers of Head Protection

ANSI Classes A, B, & C

American Optical
Apex
Bullard
CESCO & U.S. Safety
Erb Safety
Fibre Metal
Glendale
Jackson
MSA
Norton
Schuberth

ANSI Classes A & B Only

Pulmosan*
Racal
Willson Safety Products

ANSI Class B Only

Sellstrom

ANSI Class D

Bullard
Cairns & Brother
Erb
Fyrepel

Bump Caps

American Optical
Apex
Bullard
Erb
Fibre Metal
Jackson
Norton
Pulmosan
Schuberth

*By Bullard

PROTECTIVE EYEWEAR

As shown in Exhibit 3-4, most suppliers of eye protection offer both protective glasses and goggles. A number of these companies manufacture other safety products in addition to protective eyewear. Some of the manufacturers obtain parts of the products from another source.

American Optical, Gentex, Techsight, and Glendale are the only manufacturers of polycarbonate lenses. Glass lenses are made by American Optical, Titmus Optical, Fendall and Pennsylvania Optical. Parmalee Industries and American Optical produce CR-39 lenses. CESCO, U.S. Safety Co. and Parmalee are jointly owned companies.

EXHIBIT 3-4

Suppliers of Eye Protection

Glasses and Goggles

- Aden
- Airco
- American Optical
- Apex
- Bouton
- CESCO & U.S. Safety
- Fendall
- Fibre Metal
- Gateway & its Am. Safe Div.
- Glendale
- MSA
- Norton
- Pulmosan
- Sellstrom
- Titmus
- Uvex
- Willson
- Zee

Glasses Only

- Bachmann
- Hallmark
- Independent Optical Co.

Goggles Only

- American Allsafe
- Cover
- Encon
- Gentex
- Jackson
- Jones & Co.
- Kedman
- Mack Products

FACE PROTECTION

Exhibit 3-5 provides a listing of the suppliers of faceshields and welding helmets. Many of these suppliers are involved in other segments of the protective equipment market in addition to face protection. American Optical, Bullard, Apex, Glendale, MSA, Norton, Sellstrom, and U.S. Safety offers products in either the head, eye, hearing or respiratory protection areas.

EXHIBIT 3-5

Suppliers of Face Protection

Faceshields and Welding Helmets

Apex
American Optical
Fibre Metal
Jackson Safety Products
Kedman
MSA
Norton
Sellstrom
CESCO & U.S. Safety
Willson Safety Products

Faceshields Only

Airco
Bullard
CESCO
Erb
Glendale
Morse
Nalge
Pulmosan
Racal
Uvex
Zee

Welding Helmets Only

Schuberth

PROTECTIVE FOOTWEAR

A number of safety footwear producers are also involved in the consumer market with streetwear products. These companies include Knapp, International Shoe and Endicott Johnson. The major suppliers shown in Exhibit 3-6 concentrate only on protective footwear with the exception of Rainfair, and Uniroyal who are suppliers of clothing and Record and B.F. Goodrich who are suppliers of clothing and hand protection. Uniroyal manufactures neoprene boots but outsources the PVC boots.

Leather shoes are outsourced by some manufacturers, e.g. Iron Age and Record. LaCrosse, Ranger Rubber and Servus Rubber are the major U.S. producers of rubber. Other suppliers of rubber/PVC footwear buy from these companies and from foreign sources. Uniroyal manufactured neoprene boots and outsourced their PVC boots, but has recently sold its Protective Products Division to Tingley. Following the breakdown in merger negotiations with Endicott Johnson Corp., LaCross Rubber Mills approved the sale of the company to a new corporation headed by its own management.

EXHIBIT 3-6

Suppliers of Foot Protection

Leather

H.H. Brown
Georgia Boot

Hy Test
Red Wing

B.B. Walker
Weinbrenner

Rubber and/or PVC

Bata
Goodall
B.F. Goodrich
LaCross

Preview Industries (acquired Uniroyal's Red Ball Line)
Ranger Rubber
Rainfair, Inc.

Servus Rubber
Tingley (acquired Uniroyal's Protective Products Div.)
Weather-Rite

Both Leather and Rubber and for PVC

Iron Age Shoe Co.
Knapp

Lehigh
On Gard

Record Industries
Wolverine

HAND PROTECTION

The hand protection industry is highly competitive mainly because of the existence of a large number of domestic manufacturers and importers. Consolidation has occurred in the industry with the merger of Conover and Carolina and the merger of Akwell and Ansell.

There are over 70 suppliers of industrial hand protection in the U.S. most of whom are small companies with a few large companies such as Norton, Playtex, Edmont (owned by Becton Dickinson) and Dayton Flexible (owned by Baxter Travenol). A listing of the better known suppliers of hand protection is provided in Exhibit 3-7.

Companies such as Playtex and Wells offer consumer as well as industrial hand protection. Norton offers a full line of safety products including respirators, head, eye and face protection, hearing protection, and protective clothing.

PROTECTIVE CLOTHING

Exhibit 3-8 lists fifty different suppliers of protective clothing. Most of these manufacturers specialize in clothing; however some of them offer hand protection and other safety products. Mine Safety Appliances resells protective clothing to complement its full line of safety products.

David Clark, primarily a hearing protection manufacturer, also makes space suits. Disposable clothing manufacturers generally concentrate in that area as do manufacturers of chemical resistant clothing and rainwear. A number of companies specialize in turnout clothing, e.g., Janesville.

EXHIBIT 3-7

Suppliers of Hand Protection

Leather

- Advance Glove
- Allied Glove
- Boss
- Brahma
- Cardinal
- Conover & Carolina
- Elliot Glove
- Falcon Industries
- Hudson Glove
- Libra
- Magid Glove
- Monte Glove
- Norton
- Pittsburgh Glove
- Safety Clothing & Equipment
- Singer Safety
- Steel Grip
- Steiner

Cotton and Other Cloth

- Advance Glove
- Allied Glove
- Bettcher
- Boss
- Brahma
- Cardinal
- Conover & Carolina
- Hudson
- Jomac Products
- Keller Glove
- Magid Glove
- Monte Glove
- Norton
- Record
- Safety Equipment & Clothing
- Singer Safety
- Steiner

Vinyl Rubber and Synthetics, Supported and Unsupported

- Akwell and Ansell
- Best
- Boss
- Brahma
- Comasec
- Cardinal
- Conover and Carolina
- Dayton - Flexible
- Edmont
- Glover Latex
- Granite
- Hudson
- International Playtex
- Jomac Products
- Latex Glove
- Magid Glove
- Monte Glove
- Norton
- Pioneer
- Record
- Renco
- Surety

Other Heat Resistant

- A-Best
- Conover and Carolina
- Charkate
- Fyrepel
- Safety Clothing & Equipment
- Steel Grip

EXHIBIT 3-8

Suppliers of Protective Clothing

Disposable

Charkate
Daffin
Disposables, Inc.
Durafab
Edmont
Kappler
Melco
MSA*
Unitex
Worklon
Worksafe

Chemical Resistant and Rainwear

Boss
Charkate
Edmont
B.F. Goodrich*
IPCO
Jomac
MSA*
Neese
Norton
Plastex
Rainfair
Record
Uniroyal (recently acquired by Tingley Rubber)

Flame Retardant and/or Heat Resistant Including Firemen's Clothing

A-Best
Alb
Bodyguard
Boss
Charkate
Elliot
Fyrepel
C.D. Genter
Globe Mfg.
Guardline
Janesville (also own Bodyguard & Lion Uniform)
Lion Uniform
Midwestern
Morning Pride
MSA*
Pittsburgh Glove
Protexall
Racine
Record
Red Kap
Rubin Brothers
Safety Clothing & Equipment
Sager
Singer
Steel Grip
Steiner
Worklon
Workrite
Wheeler

Other

David Clark
ILC Dover
Standard Safety
Wheeler

*Not a Manufacturer

SECTION IV

THE MARKET FOR PERSONAL PROTECTIVE CLOTHING AND EQUIPMENT

RESPIRATORY PROTECTION

In 1981, the market for respiratory protection devices in dollars was approximately $272 million. The total market was comprised of $105 million for reusable air purifying respirators (non powered), $48 million for disposable respirators, $17.5 million for dust masks, $16.5 million for powered air purifying devices, $55 million for self-contained breathing apparatus (SCBA), and $30 million for supplied air respirators, not including SCBA. The respiratory protection market is projected to grow at 6%, faster than the workforce. The disposable respirator segment should grow at 8-9% with other segments such as SCBA growing at a slower rate.

Sales of respiratory protection devices for 1981 in terms of units are provided in Exhibit 4-1. Also shown is the average unit cost of the various respirators. The market shares of the manufacturers of respiratory protection devices are shown in Exhibit 4-2. The position of these manufacturers in each of the different segments of the respiratory protection market may be viewed in Exhibits 4-3 through 4-5.

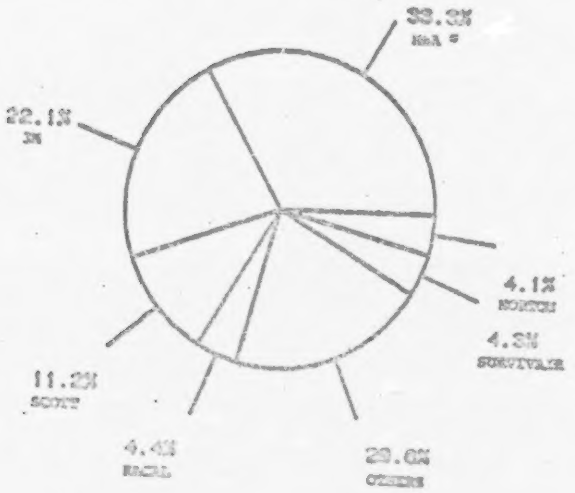
EXHIBIT 4-1

Sales of Respiratory Protection Devices for 1981

	Mil Units	Average Cost/Unit
Disposable	107	$ 0.45
Nuisance Dust Mask	80	$ 0.22
Reusable Non-powered Air Purifying	7	$ 15.00
Powered Air-Purifying	.05	$ 300.00
Self-Contained Breathing Apparatus	.85	$ 650.00
Supplied Air, Not Including SCBA	.34	$ 89.00

EXHIBIT 4-2

MARKET SHARES—1981
RESPIRATORY PROTECTION DEVICE MANUFACTURERS



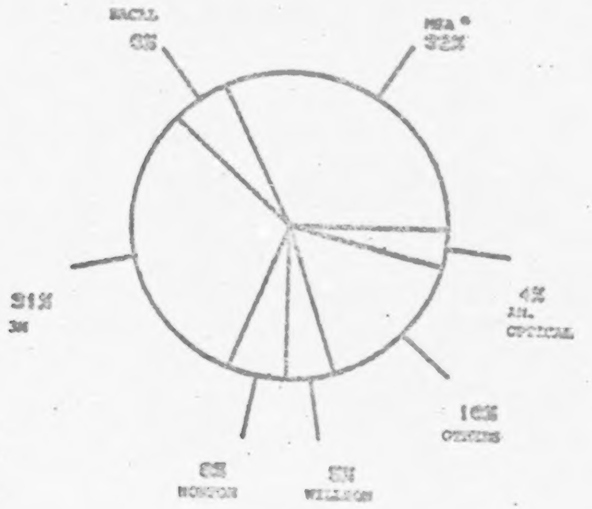
*Not including units made for others.

Exhibit 4-3 provides market shares for the air purifying respirator segment and the atmosphere supplying respirator segment. Market shares of companies manufacturing specific types of atmosphere supplying respirators are shown in Exhibit 4-4. Air purifying respirators include non powered reusable, powered air purifying, and disposable. The market positions of the companies manufacturing these respirators are shown in Exhibit 4-5.

EXHIBIT 4-3

SPRINGBORN MANAGEMENT SERVICES INC

MARKET SHARES-1981
AIR-PURIFYING RESPIRATORS INCL POWERED RESPIRATOR MFGS



MARKET SHARES-1981
ATMOSPHERE SUPPLYING RESPIRATOR MANUFACTURERS
SUPPLIED AIR AND SCBA

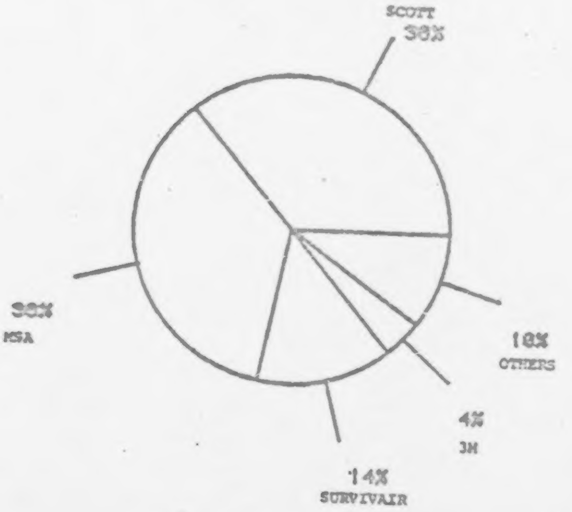
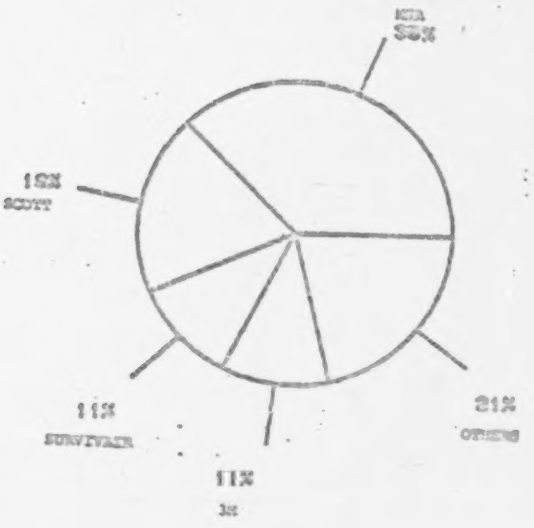


EXHIBIT 4-4

MARKET SHARES-1981
SUPPLIED AIR RESPIRATOR MANUFACTURERS
EXCLUDING SELF-CONTAINED BREATHING APPARATUS(SCBA)



MARKET SHARES-1981
SELF-CONTAINED BREATHING APPARATUS (SCBA) MFGS

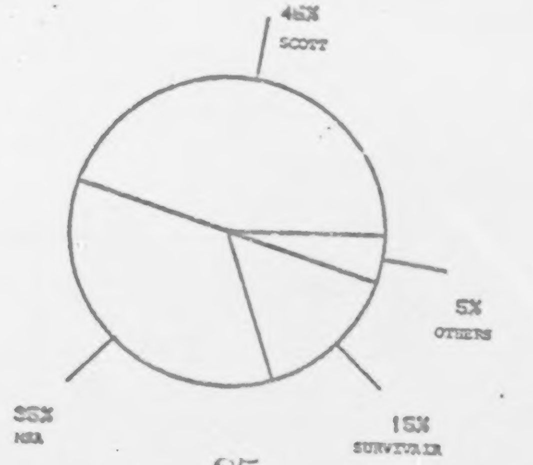
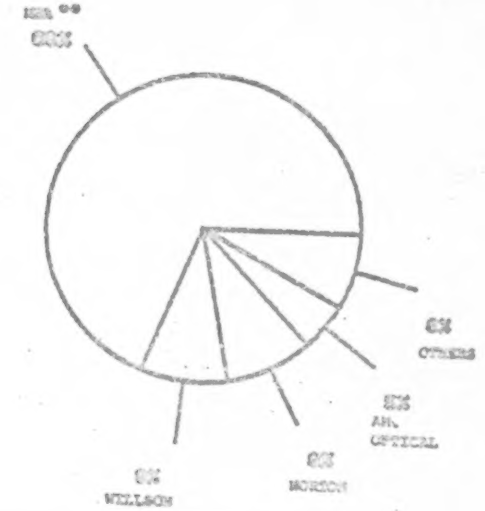


EXHIBIT 4-5

MARKET SHARES-1981
NON-POWERED REUSABLE AIR-PURIFYING RESPIRATOR MFGS



MARKET SHARES-1981
POWERED AIR PURIFYING RESPIRATOR MFGS

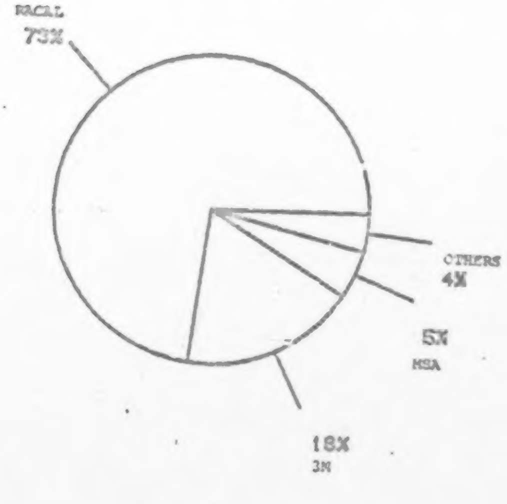
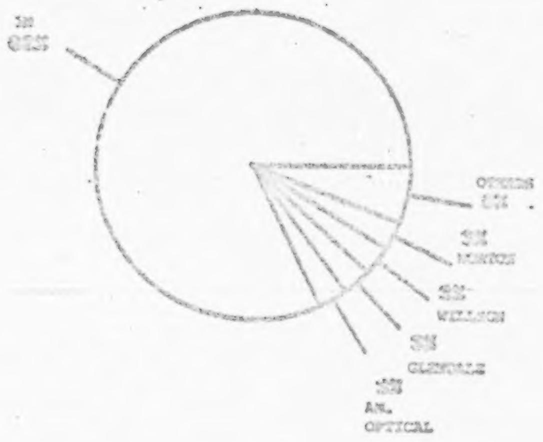


EXHIBIT 4-5 Continued

MARKET SHARES—1981
DISPOSABLE RESPIRATORS & NUISANCE DUST MASKS MFGS



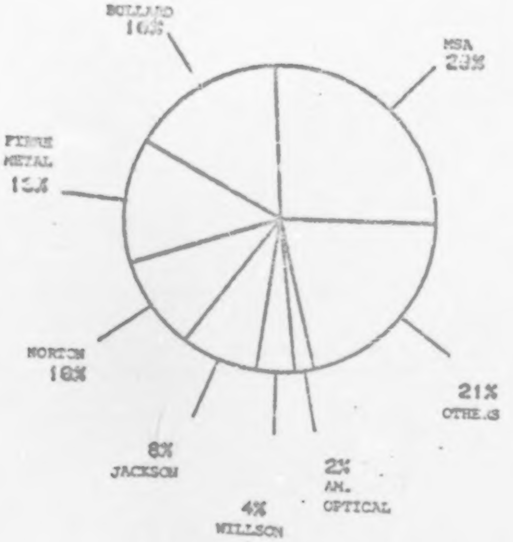
HEAD PROTECTION

The head protection segment of the personal protective equipment and clothing market has reached the point of saturation with growth dependent on the state of the economy and the size of the workforce. The present level of unemployment has exercised a negative impact on the demand for hard hats, but the situation should improve when the economy recovers. The hard hat market should experience an annual growth rate of about 1.6%, about the same percentage as the total number of non-agricultural employees.

For 1981, the market for head protection was approximately 9.5 million units or $26.6 million based on an average distribution cost of $2.80/unit. The user cost is about $4.25/unit, and the dollar value should increase at about the same rate as the cost of energy. Exhibit 4-6 provides an estimate of the market shares of the various hard hat manufacturers.

EXHIBIT 4-6

MARKET SHARES-1981
HEAD PROTECTION MANUFACTURERS



HEARING PROTECTION

The hearing protection market is comprised of disposable and reusable plugs, bands, muffs, and communication devices. For 1981, the hearing protection market in dollars was estimated at $37.1 million on the distributor level and $56.5 million on the user level. Hearing protection should grow at 10-15% annually up to 1984 because of recent regulations from the Occupational Safety and Health Administration. Exhibit 4-7 shows the market size and the average unit cost for various types of hearing protection devices on the distributor level.

EXHIBIT 4-7

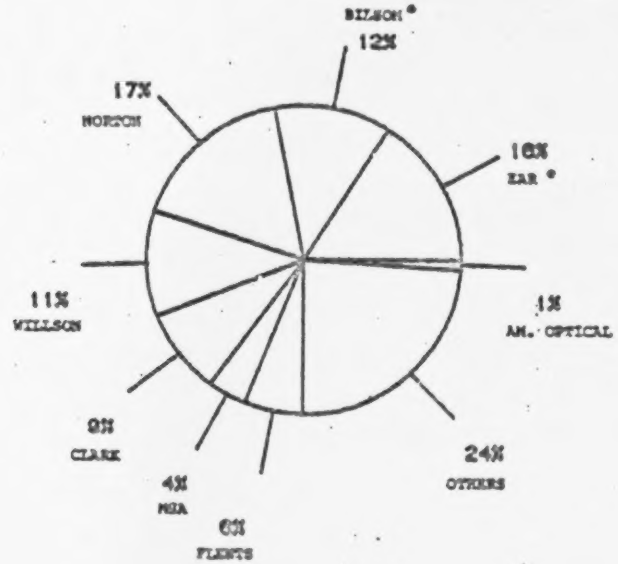
The Hearing Protection Market for 1981

	Market Size Million $	Average Cost
Reusable Plugs		
PVC Plugs	2.7	$0.50 / pair
Silicone Rubber Plugs	[illegible]	$0.60 / pair
Disposable Plugs		
Disposable Foam Plugs	[illegible]	$0.13 / pair
Other Disposable Plugs	[illegible]	$0.05 / pair
Bands	2.5	$3.75
Muffs	9.0	$7.50
Communication Devices	7.0	Varies

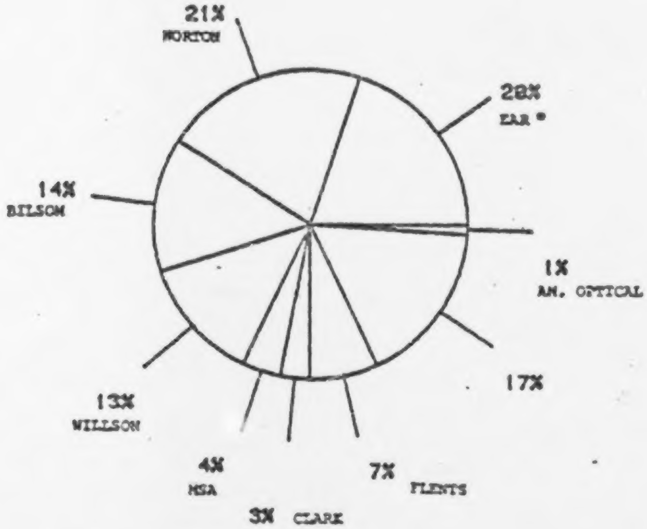
Exhibit 4-8 provides market shares of the various manufacturers of hearing protection. The market shares of these companies in specific segments of the hearing protection market are in Exhibits 4-9 through 4-12. Companies supplying reusable plugs are shown in Exhibit 4-9. Market shares of manufacturers of ear muffs and communication devices are detailed in Exhibit 4-10 with suppliers of disposable plugs and bands shown in Exhibit 4-11. The disposable plug segment is divided into foam plugs and plugs other than foam (see Exhibit 4-12).

EXHIBIT 4-8

MARKET SHARES-1981
HEARING PROTECTION MFG, INCLUDING COMMUNICATION DEVICES



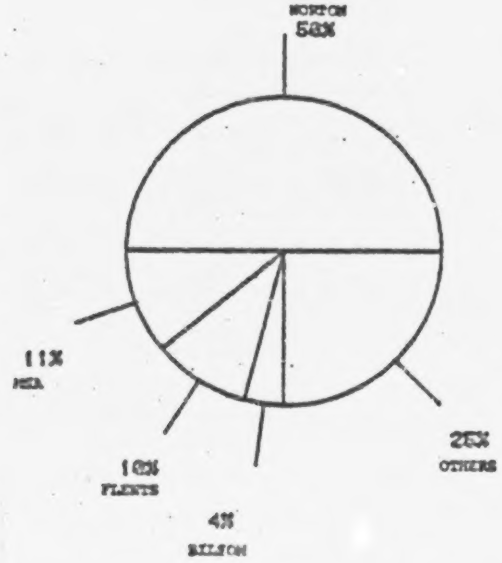
MARKET SHARES-1981
HEARING PROTECTION MANUFACTURERS
NOT INCLUDING COMMUNICATION DEVICES



*Not including plugs made for others

EXHIBIT 4-9

MARKET SHARES-1981
SUPPLIERS OF REUSABLE SILICONE RUBBER PLUGS



MARKET SHARES-1981
SUPPLIERS OF REUSABLE PVC PLUGS

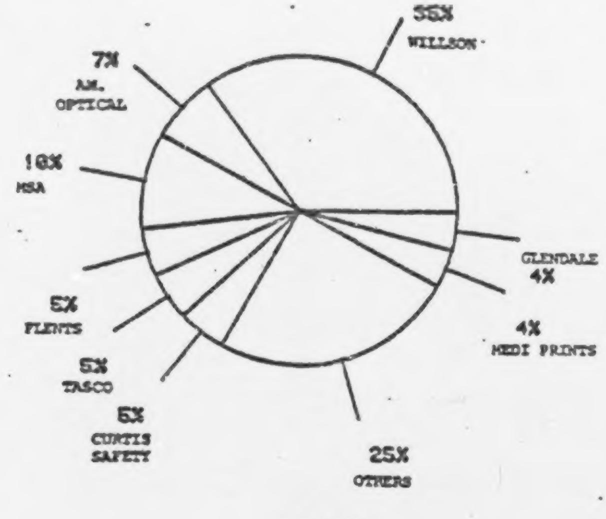
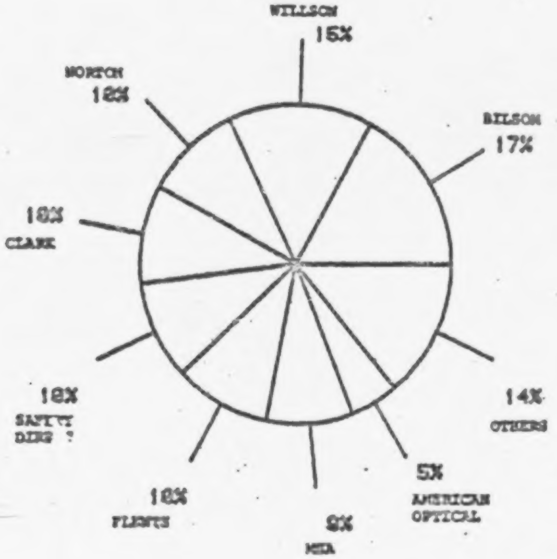


EXHIBIT 4-10

MARKET SHARES–1981
SUPPLIERS OF EAR MUFFS



MARKET SHARES–1981
SUPPLIERS OF COMMUNICATION DEVICES

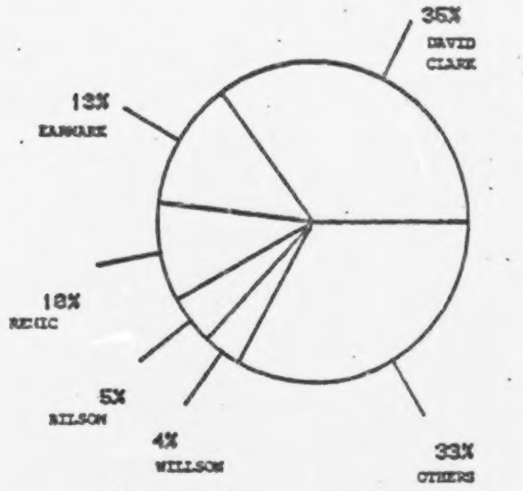
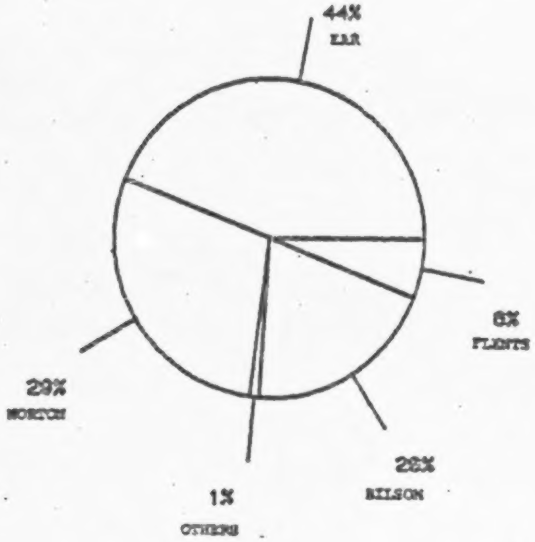


EXHIBIT 4-11

MARKET SHARES-1981
SUPPLIERS OF DISPOSABLE EAR PLUGS



MARKET SHARES-1981
SUPPLIERS OF BANDS

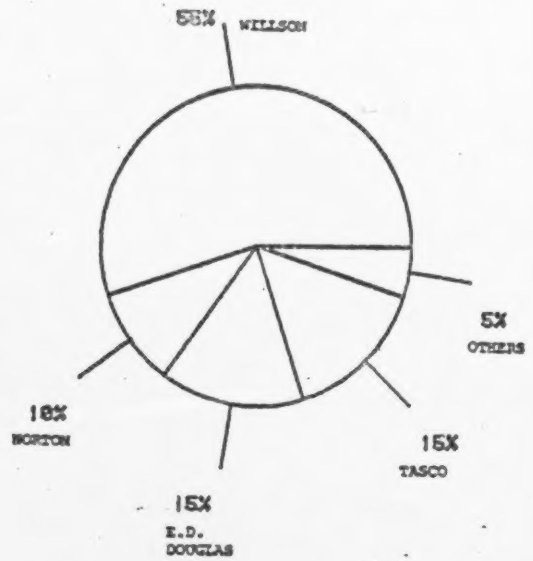
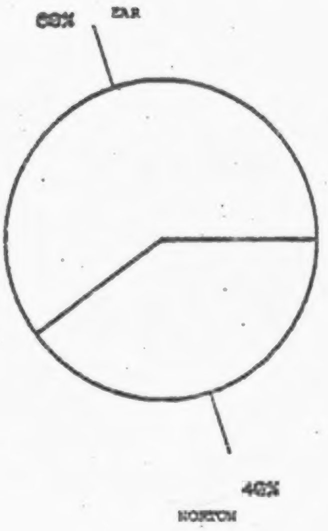


EXHIBIT 4-12

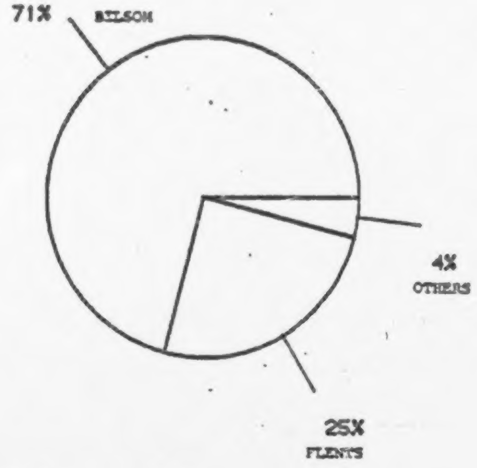
MARKET SHARES-1981

SUPPLIERS OF DISPOSABLE FOAM EAR PLUGS



MARKET SHARES-1981

SUPPLIERS OF DISPOSABLE EAR PLUGS OTHER THAN FOAM



PROTECTIVE EYEWEAR

The total market for protective eyewear was about $149 million in 1981 compared with $160 million in 1979. This figure includes the three major product segments: prescription glasses, non-prescription glasses (plano) and goggles.

The market for plano eyewear ranges between 15-17 million pairs/year depending on the size of the workforce. Compared with the high figure of 18 million units or $54 million of plano eyewear for 1979, the market in 1981 was 16 million units or $48 million. The 1982 figure is projected at the same level as 1981 or perhaps 5% below that figure. Long term growth should be limited to 1% since the eye preotection market is already saturated.

Approximately 52% of the non-prescription safety glasses have lenses of polycarbonate compared with 5% in 1975. Polycarbonate's popularity is expected to grow possibly reaching 60% because of its high impact strength, the development of improved abrasion resistant coatings, and the fact that its price is 10% below glass. The price has not increased in three years because of over capacity with polycarbonate lenses being molded by Gentex along with American Optical, Techsight and Glendale. Glass' share at 46% is expected to diminish, and CR-39 lenses may also lose some of its 2% share.

The market for prescription safety glasses is $70 million or 3.5 million units. Of this total, 80% have glass lenses, 15% have CR-39 lenses and 5% have lenses of polycarbonate. The need for a large number of molds and the lack of a suitable grinding process for prescription multi focal lenses have limited polycarbonate's penetration in the protective prescription eyewear market. American Optical is the only company offering polycarbonate prescription multi focals. Polycarbonate will show greater penetration of the market as more multi focal prescription lenses are offered.

The replacement rate for prescription eyewear is two to three years compared with six months to one year for plano eyewear.

The goggle market encompasses goggle types such as chemical splash, welding, and chippers goggles with the largest segment being chemical splash goggles. In 1981, the goggle market was approximately $25 million or 9.25 million units. The average cost of goggles was $2.70/unit. Visitor's safety eyewear totalled around $6 million.

Exhibit 4-13 shows the market shares of the companies manufacturing plano eyewear, prescription eyewear and goggles.

FACE PROTECTION

In 1981, the market for face shield headwear was 2-3 million units or $8 million based on a distributor cost of $4.00/unit. For faceshield visors the market is $20 million or 8 million units, approximately four (4) times the number of headgear. The market for welding helmets was 1.7 million units which based on a distributor cost of around $16/unit represents $26 million. The face protection market is saturated and growth greater than 1% is unlikely. The market shares of the companies manufacturing faceshields and welding helmets are depicted in the pie charts in Exhibit 4-14.

PROTECTIVE FOOTWEAR

Protective footwear includes shoes and boots made of leather, rubber or polyvinyl chloride. About 70% of the protective footwear is steel toe.

In 1981, the leather protective footwear market was 9.5 million pairs or $335 million. Approximately 7.6 million pairs of molded boots were sold in 1981, representing $168 million. Although 70-75% of the molded footwear was rubber, PVC is expected to penetrate 30% of the market within two years and 50% within five years due to its lower price. PVC steel toe boots cost $10.50/pair on the distributor level, compared with $25.00 for rubber. Overall growth in the protective footwear market was 2% annually in the 1970s and growth should be limited to 3% in the 1980s. The market shares of the companies supplying protective footwear are shown in Exhibit 4-15.

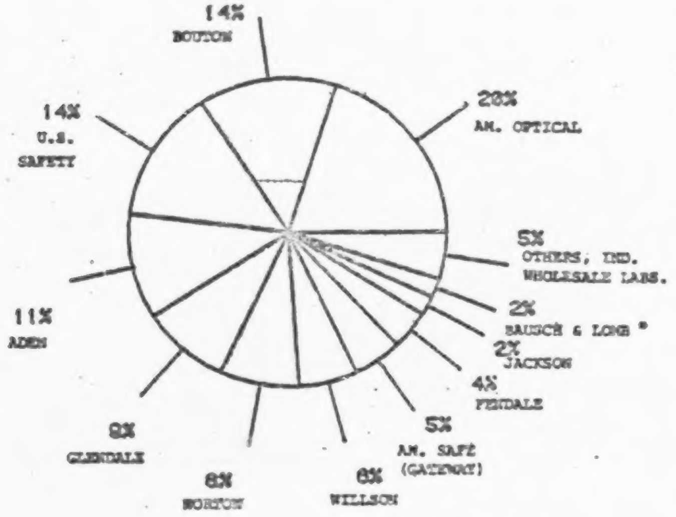
HAND PROTECTION

The hand protection market includes gloves described as fabric, leather, leather palm, supported, unsupported and heat resistant. Exhibit 4-16 shows the total market in units and in dollars. Growth in hand protection was 1.9% from 1970-1979. At present the market is stagnant.

EXHIBIT 4-13

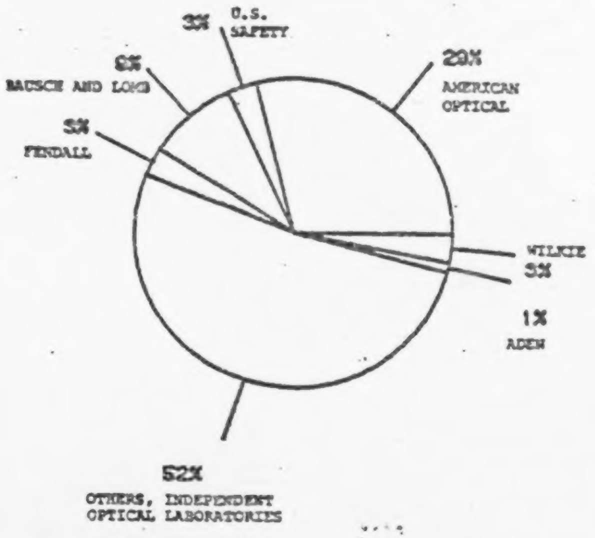
MARKET SHARES-1981

PLANO PROTECTIVE EYEWEAR MANUFACTURERS



MARKET SHARES-1981

PRESCRIPTION SAFETY EYEWEAR MANUFACTURERS



*Bausch and Lomb has exited the market.

EXHIBIT 4-13 Continued

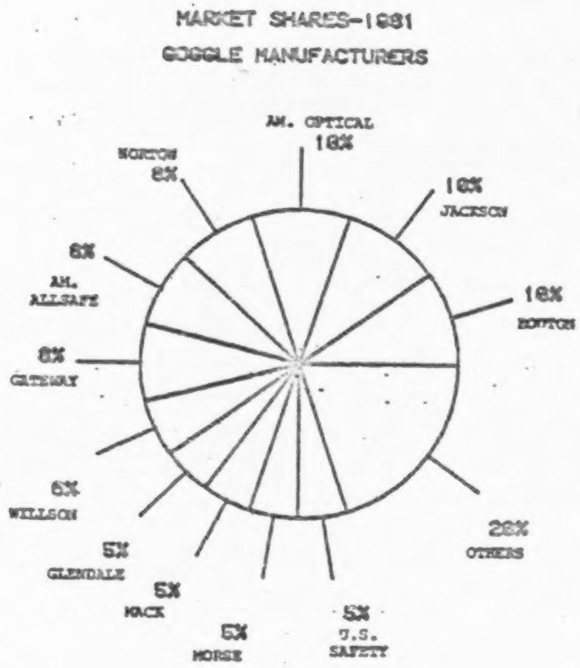
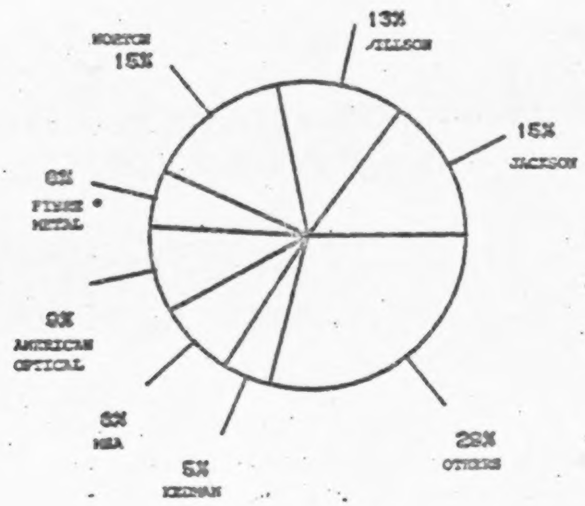
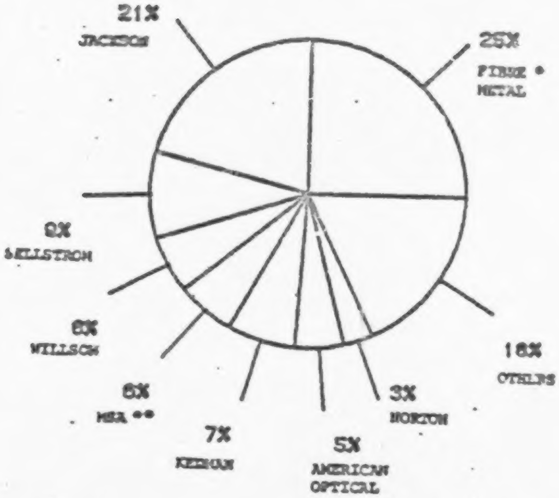


EXHIBIT 4-14

MARKET SHARES-1981
FACE SHIELD MANUFACTURERS



MARKET SHARES-1981
WELDING HELMET MANUFACTURERS

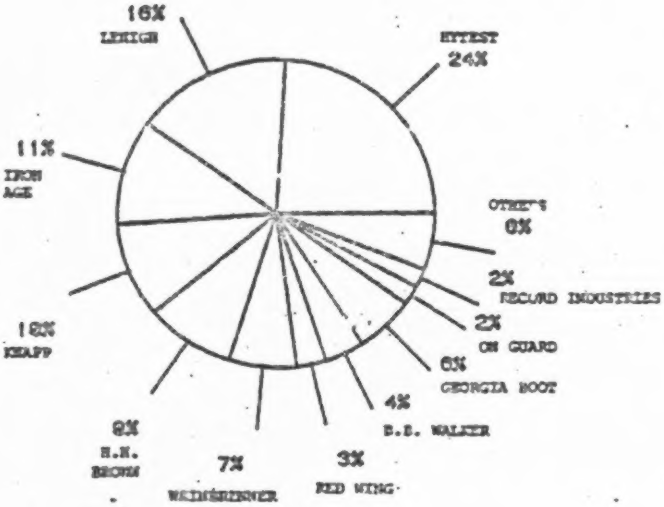


*Not including units made for others.

**Some made by Fibre Metal

EXHIBIT 4-15

MARKET SHARES-1981
LEATHER PROTECTIVE FOOTWEAR MANUFACTURERS



MARKET SHARES-1981
RUBBER/PVC PROTECTIVE FOOTWEAR MANUFACTURERS

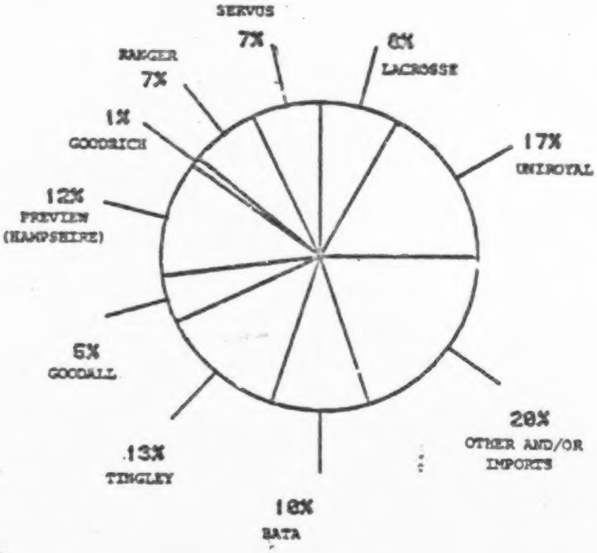


EXHIBIT 4-16

The Hand Protection Market for 1981

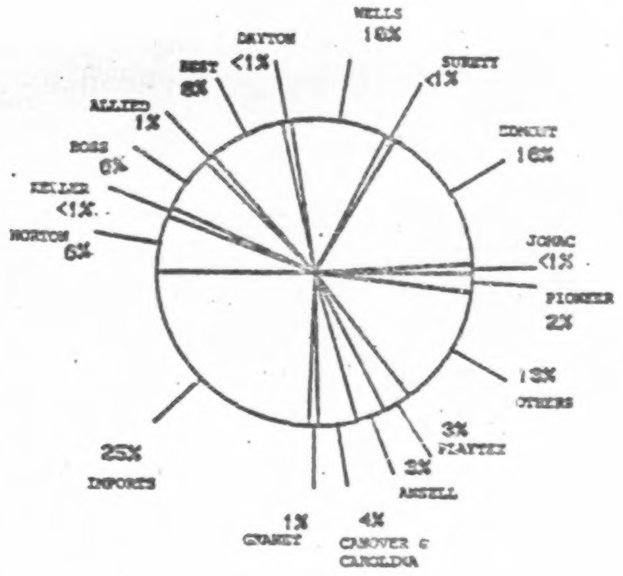
	Million $	Million Dozen	Million Pairs	% Imports
Fabric, single and double canton flannel, fleeced cotton jersey circular knit cotton and other fabrics	$ 174	22.3	268	28.5
Leather palm	$ 146	3.5	42	73
Leather	$ 147	2.3	27.6	16.7
Supported	$ 121	6.24	74.8	5.6
Unsupported	$ 173	44.35	532	
Other	$ 29			
	$ 790			

Heat resistant gloves of asbestos and asbestos substitutes are included in the other category each contributing 500,000 to 1,000,000 pairs. By 1984, the asbestos glove market should diminish to 5,000-25,000 pairs or less.

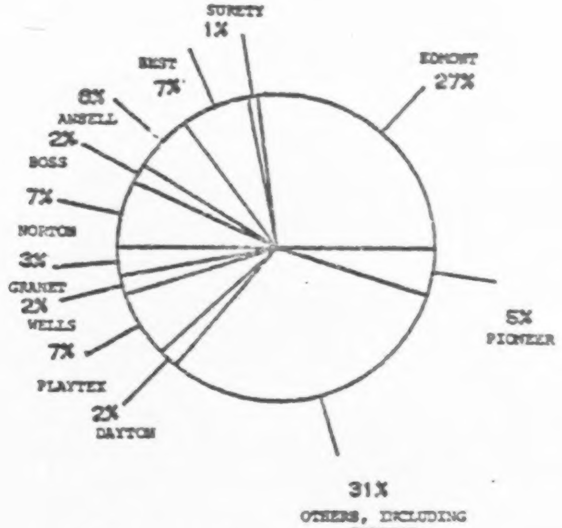
The market shares of the various suppliers of gloves are provided in Exhibit 4-17.

EXHIBIT 4-17

MARKET SHARES-1981
GLOVE MANUFACTURERS



MARKET SHARES-1981
SUPPORTED AND UNSUPPORTED GLOVE MFGS



PROTECTIVE CLOTHING

The protective clothing market consists of disposable clothing, heat resistant clothing, firemen's clothing (turn-out), encapsulated suits, and rainwear and chemical resistant clothing. The market sizes of the various types of protective clothing are shown in Exhibit 4-18.

EXHIBIT 4-18

Protective Clothing Market - 1981

	Thousands of Garments	Million $
Disposable	40,000 - 50,000	36
Rainwear and Chemical Resistant	4,895	54
Encapsulated suits		
Industrial	4	6
Government	2	
SEF Modacrylic	375	6
FR Cotton	2,500	40
Leather	500	15
Aluminized	125	90
Asbestos	100 - 150	
Nomex		
Industrial	350	18
Military	524	
Turn-out	229	22.9

Turn-out clothing for firefighters includes turn-out coats, pants, and accessories such as pockets and knee patches. Seventy percent (70%) of the clothing is made of Nomex with 30% of cotton duck, or aluminized fabric such as glass, Kevlar or rayon. Flame retardant rayon provides greater absorbancy, is less expensive than Nomex, and may be used in a blend with Nomex. Kevlar has been described as difficult to dye and not as abrasion resistant. Studies are being conducted on clothing of Nomex, Kevlar and Celanese's polybenzimidazole (PBI).

The market for turn-out clothing should not change significantly. At present, the average distributor cost is $110 for a turn-out coat and $63-85 for pants. Market shares of companies supplying turn-out clothing are provided in Exhibit 4-19.

Greater growth is expected in the disposable clothing segment with some projections as high as 10% annually. As shown in Exhibit 4-19, there are a number of disposable manufacturers, more than twenty-five. The majority of the clothing is coveralls mostly of Tyvek material. The average distributor cost for disposable garments is $0.88/garment.

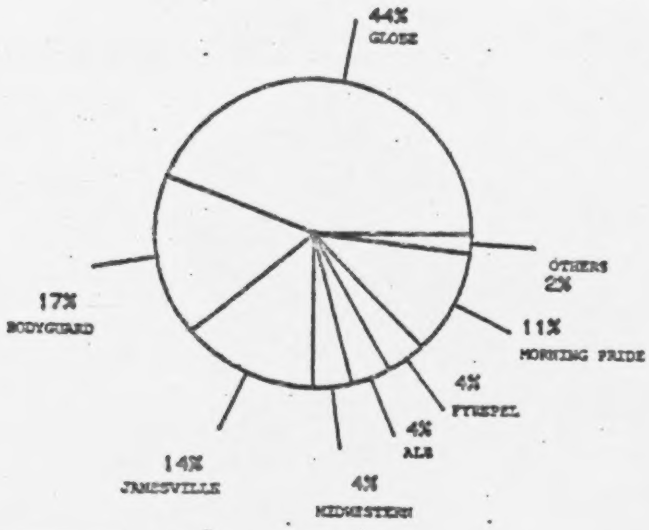
Clothing of Nomex other than turn-out clothing is used by industry and the military. The average cost for a Nomex garment on the distributor level is $51.00 presently. The market is dominated by a few companies (see Exhibit 4-20).

Although J.P. Stevens has discontinued production of SEF modacrylic fabric, Westex Mills is expected to begin production. Increased costs of the fabric should increase the market for SEF modacrylic garments from $4.1 million to over $5 million. A number of the makers of SEF modacrylic garments also manufacture garments of flame retardant cotton. Exhibit 4-21 shows the market shares of the manufacturers of SEF modacrylic garments and FR cotton garments.

Rainwear and chemical resistant garments are fabricated of an outer covering of neoprene, PVC or polyurethane. The market penetration of imports is 50% in units, but since these garments are lower-priced at $10/garment compared with the average cost of $16/garment, the market share of imports in terms of dollars is 38% (see Exhibit 4-22). The rainwear and chemical resistant garment segment should grow at an annual rate of less than 5%.

EXHIBIT 4-19

MARKET SHARES-1981
TURN-OUT CLOTHING MANUFACTURERS



MARKET SHARES-1981
COMPANIES PRODUCING DISPOSABLE CLOTHING

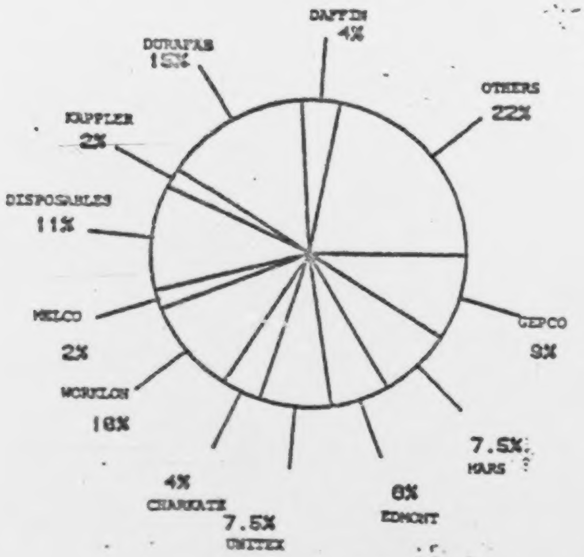
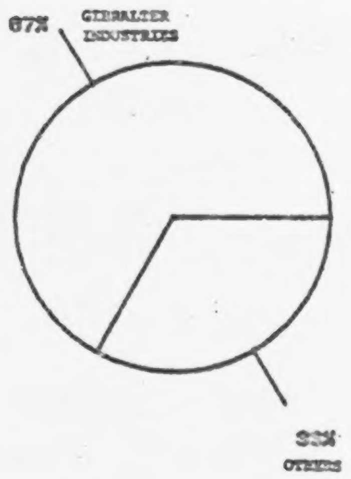


EXHIBIT 4-20

MARKETS SHARES-1981
NOMEX CLOTHING MANUFACTURERS



MILITARY

MARKET SHARES-1981
NOMEX CLOTHING MANUFACTURERS
INDUSTRIAL

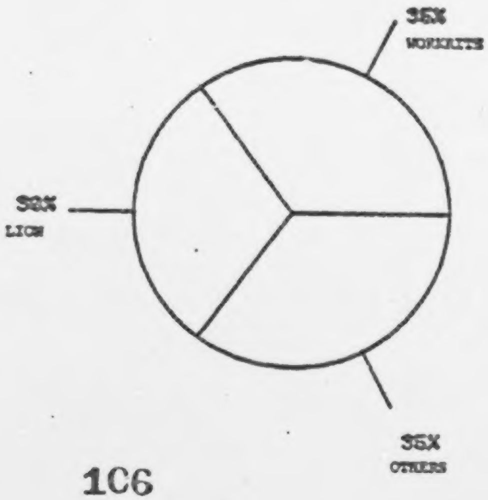
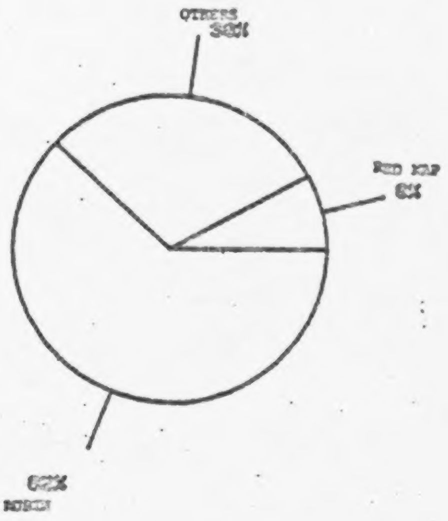


EXHIBIT 4-21

MARKET SHARES-1981

COMPANIES PRODUCING GARMENTS OF SEF MODACRYLIC



MARKET SHARES-1981

COMPANIES PRODUCING GARMENTS OF FR COTTON

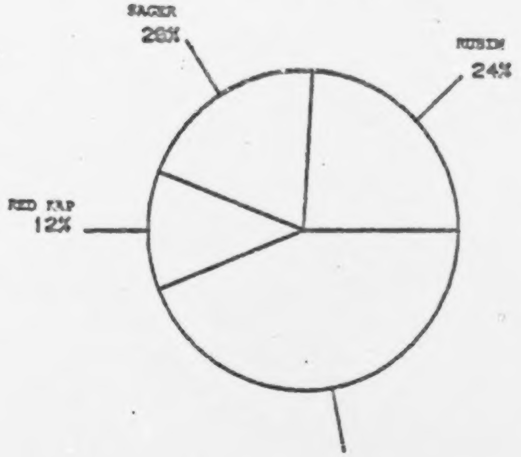
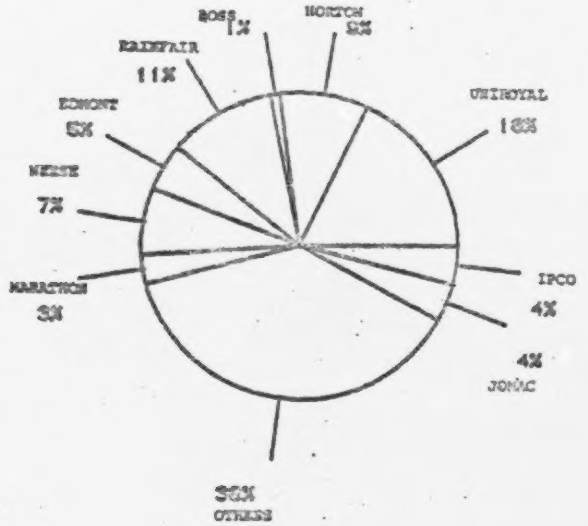


EXHIBIT 4-22

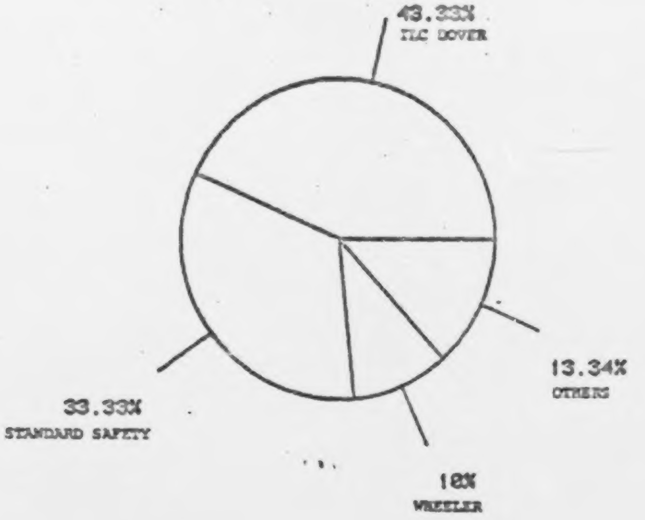
MARKET SHARES-1981

PROTECTIVE RAINWEAR & CHEMICAL RESISTANT CLOTHING MFGS



MARKET SHARES-1981

COMPANIES PRODUCING ENCAPSULATED SUITS
(INDUSTRIAL AND GOVERNMENT)



Although the number of encapsulated suits manufactured in 1981 was small, the retail cost of the suit was high, ranging from $500-2,000. The suits are used in industrial environments and by the government for NASA, the Coast Guard, and the Army.

The suits are fabricated of PVC, butyl and chlorinated polyethylene. Replacement occurs at a rate of one every five years, and the market is not expected to grow significantly.

Significant growth is not expected for leather and aluminized garments. At present the market for asbestos substitutes in units is equal to that for asbestos garments, however, the market for asbestos clothing is expected to decline dramatically.

SECTION V

CHANNELS OF DISTRIBUTION OF PERSONAL PROTECTIVE EQUIPMENT AND CLOTHING

SAFETY PRODUCT DISTRIBUTORS

The predominant means of distribution of personal protective devices is from the manufacturer to the user through the safety product distributor. There are over 500 distributors of safety products in the United States. Mine Safety Appliances Company is the only major manufacturer of protective equipment that sells only direct to the user. A few manufacturers sell mainly through distributors but handle large accounts through their own sales representatives.

The distributor's function is to sell, service and stock the protective equipment. The equipment may be purchased from a safety specialist whose income depends solely upon the sales of the safety equipment or from a general distributor whose sales of safety equipment are only a part of his income. The distributor monitors market acceptance of products. His success depends on his ability to supply quality equipment as soon as possible.

In addition to having products that are available when needed, the distributor's other priorities include having products from a manufacturer with a strong reputation which facilitates selling a product, having knowledgeable manufacturer's representatives who visit the distributor frequently to become informed of the user's needs and to communicate to the distributor what is developing at the manufacturer's level, and having adequate advertising of the product either solely through national advertising or by also contributing to yellow page advertisements and safety demonstrations.

Distributors were questioned about the importance of brand name recognition. A number of distributors mentioned that 50-75% of the requests are for a brand name because of advertising and because the distributors' catalogs mention brand names. This is especially true for replacement of protective equipment. Some distributors mentioned that brand names were not frequently requested.

Since there are a large number of manufacturers and products, it is more profitable for the distributor to obtain larger lots and stock only a few items. The manufacturer is responsible for keeping the distributor well stocked. This also reduces the manufacturer's cost in storage, transportation and handling.

The distributor can obtain price breaks in a number of ways. First, the "pre-freight plan" allows the distributor to purchase above a predetermined level and have the equipment shipped free of charge. Second, a minimum order purchase discounts the products according to quantities purchased. Sometimes a minimum level must be attained before a discount is observed. Depending on the manufacturer's policy, the orders may be mix and match or only on one item for the discount. Third, the "blanket order" policy allows a large lot discount or a pre-freight deal on small lot purchases if the distributor purchases a predetermined amount of personal protective equipment or clothing over a given period of time.

Another benefit for distributors is training programs which inform them of products, prices, applications, government regulations and other developments. The programs may be conducted by manufacturers, the Safety Equipment Distributors Association or the Industrial Safety Equipment Asociation. The manufacturer's representative is the most common source of information for the distributors.

Import/Export

Imports impact upon a few segments of the protective equipment and clothing market. The greatest effect is experienced in hand protection and protective clothing, coming mostly from Asia. In 1981, imports accounted for over 28% of the gloves made of fabric. Import penetration of the leather palm glove market is 73% and almost 17% for all leather gloves. In the supported and unsupported area, imports accounted for 5.6% of the total market. Nearly one-half of the rainwear and chemical resistant market is imported with the imported garments being predominantly lower priced PVC garments. PVC footwear is mostly imported. Respiratory, head, eye and face protection are dominated by domestic companies with a few small European-based companies such as Schuberth and Uvex supplying the U.S. market. Another European company, Bilsom, has a large share of the market for hearing protection. These companies have offices located in the United States.

A few U.S. manufacturers supply protective equipment to Canada and other countries. At present the European market for personal protective equipment and clothing is saturated and future sales are dependent upon replacements. Some growth may occur in Italy if the government promulgates more stringent regulations.

European manufacturers of protective equipment are mostly privately owned and small to medium in size. In Europe, direct marketing of respirators and shoes does occur. Manufacturers stock company shoe stores. Most other types of protective equipment and clothing especially gloves and protective clothing are sold through distributors.

SECTION VI

MARKET SATURATION OF PROTECTIVE EQUIPMENT AND CLOTHING IN MAJOR INDUSTRIES

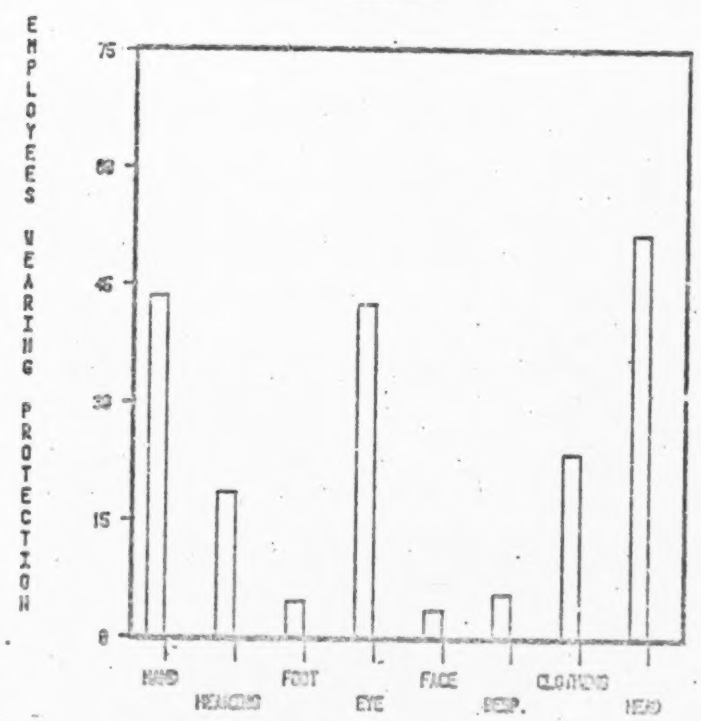
A survey of users of personal protective equipment and clothing in the major industry classifications was conducted to determine the market saturation of the equipment in different industries. Users of personal protective equipment and clothing in such industrial sectors as agriculture, forestry, mining, construction, manufacturing and public utilities were selected. Each of these sectors include a number of standard industrial classification (SIC) codes. The two digit SIC codes addressed in this survey are:

Forestry (08)
Metal Mining (10)
Anthracite Mining (11)
Bituminous Coal and Lignite Mining (12)
Oil and Gas Extraction (13)
Nonmetallic Minerals Except Fuels (14)
General Building Contractors (15)
Heavy Construction Contractors (16)
Special Trade Contractors (17)
Food and Kindred Products (20)
Tobacco Manufacture (21)
Textile Mill Products (22)
Apparel and Other Textile Products (23)
Lumber and Wood Products (24
Furniture and Fixtures (25)
Paper and Allied Products (26)
Printing and Publishing (27)
Chemicals and Allied Products (28)
Rubber and Miscellaneous Plastics Products (30)
Leather and Leather Products (31)
Stone, Clay, and Glass Products (32)
Primary Metal Industries (33)
Fabricated Metal Products (34)
Machinery, Except Electrical (35)
Electric and Electronic Equipment (36)
Transportation Equipment (37)
Instruments and Related Products (38)
Miscellaneous Manufacturing Industries (39)
Electric, Gas and Sanitary Services (49)

Companies involved in these industries were asked to indicate the percentage of their employees who were required to wear the protective equipment. The tabulated results showing the use penetration of protective equipment by industry classification are provided in the graphs in Exhibits 6-1 through 6-15 to facilitate comparison by SIC code and by type of equipment.

EXHIBIT 6-1

FORESTRY (08)



METAL MINING (10)

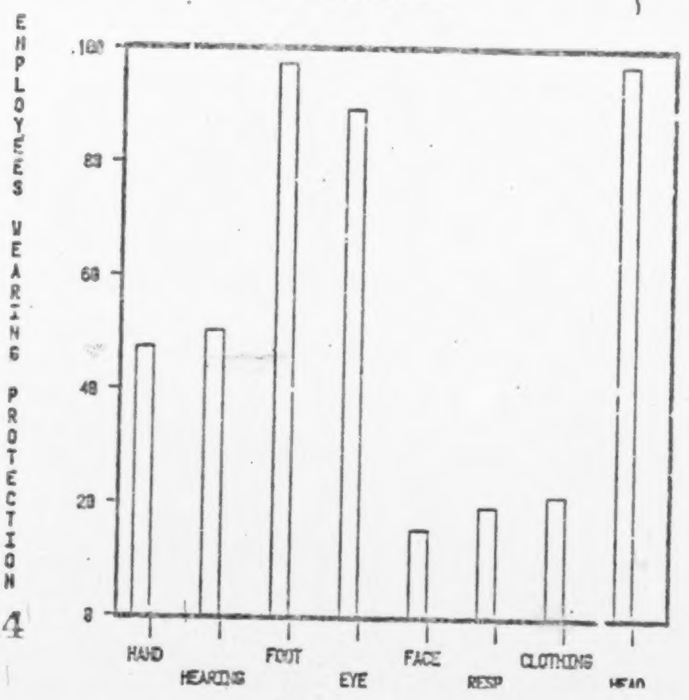
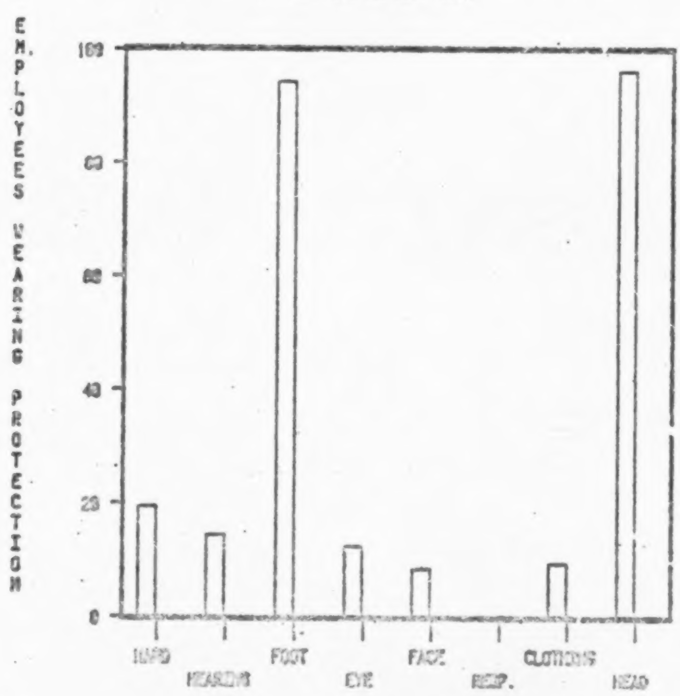


EXHIBIT 6-2

ANTHRACITE MINING (11)



BITUMINOUS COAL & LIGNITE MINING (12)

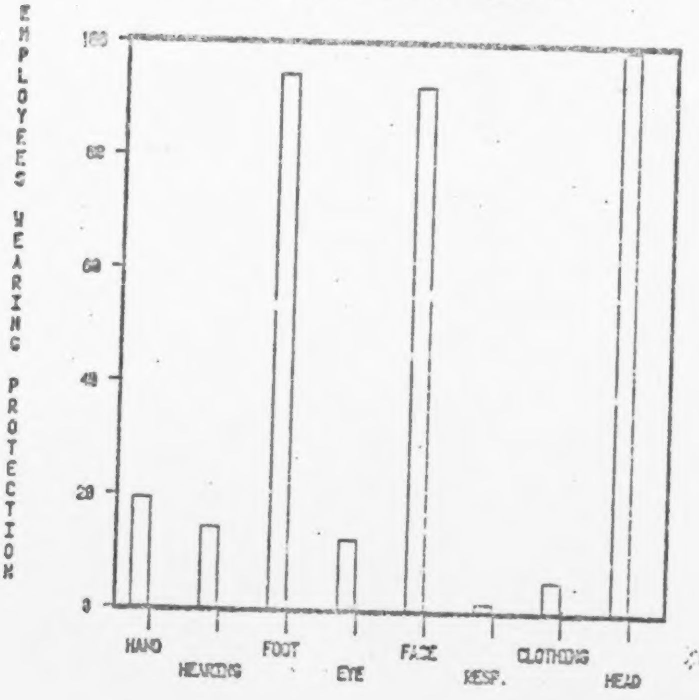
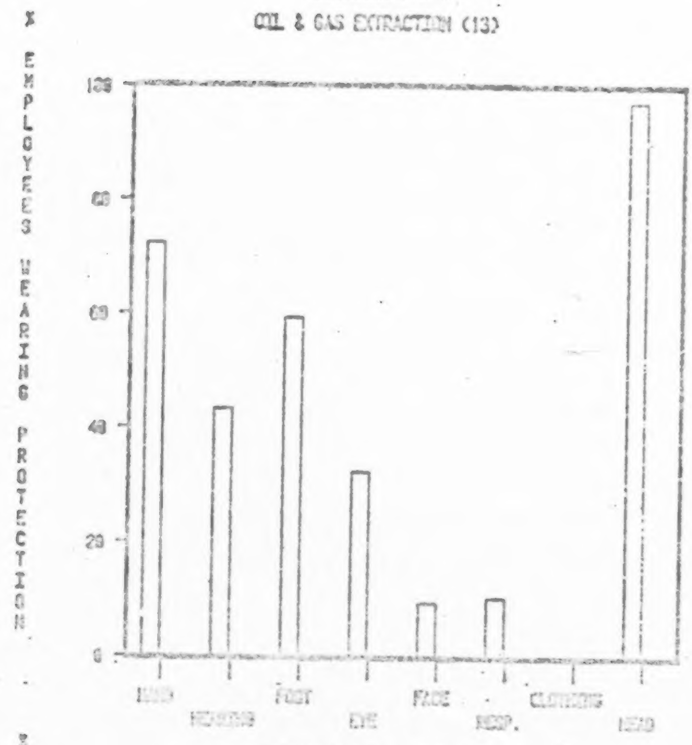


EXHIBIT 6-3

OIL & GAS EXTRACTION (13)



NONMETALLIC MINERALS (14)

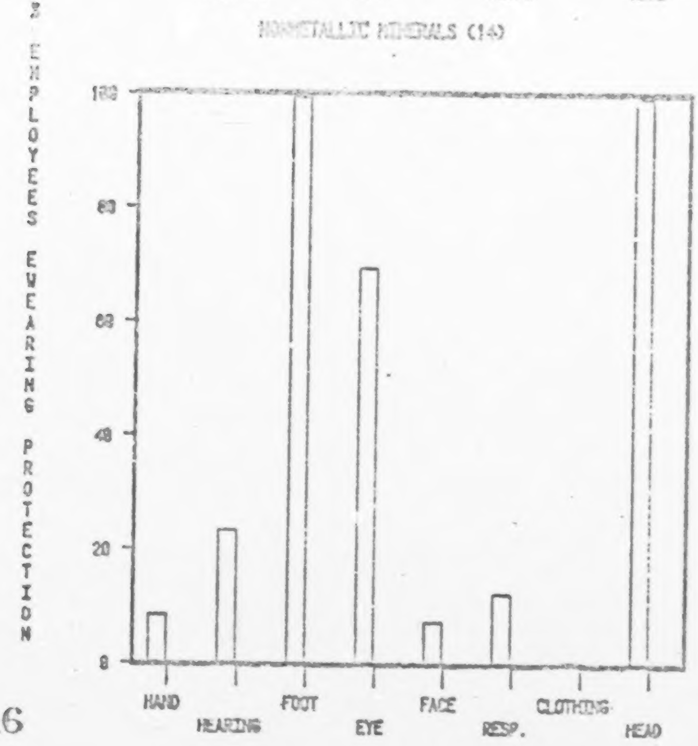
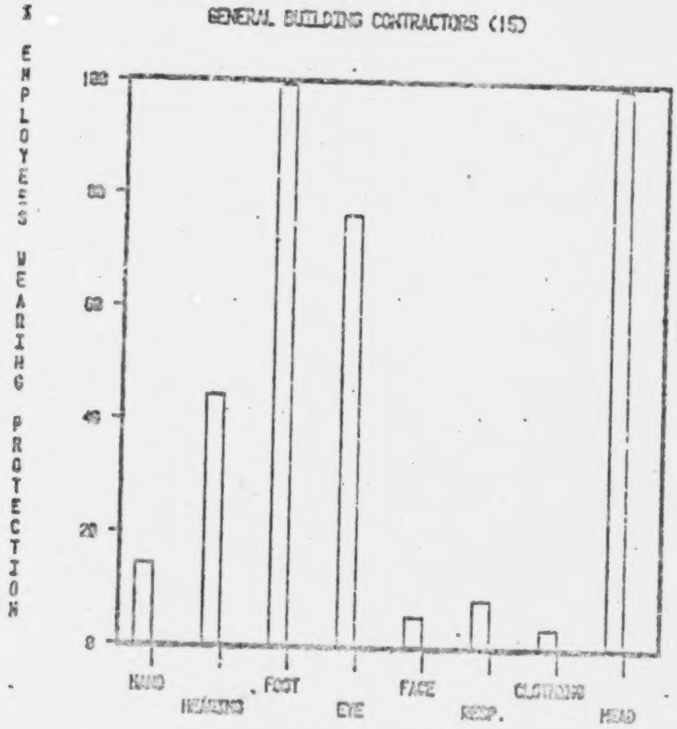
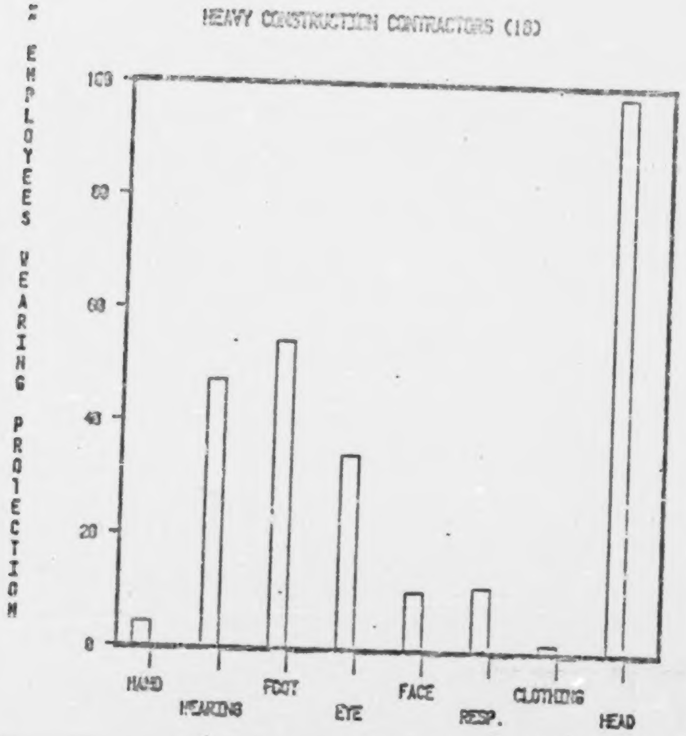


EXHIBIT 6-4

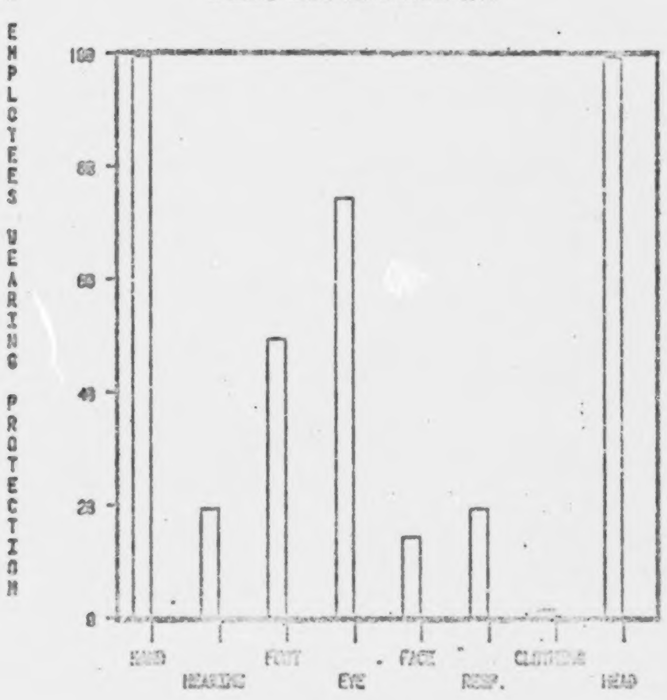


GENERAL BUILDING CONTRACTORS (15)

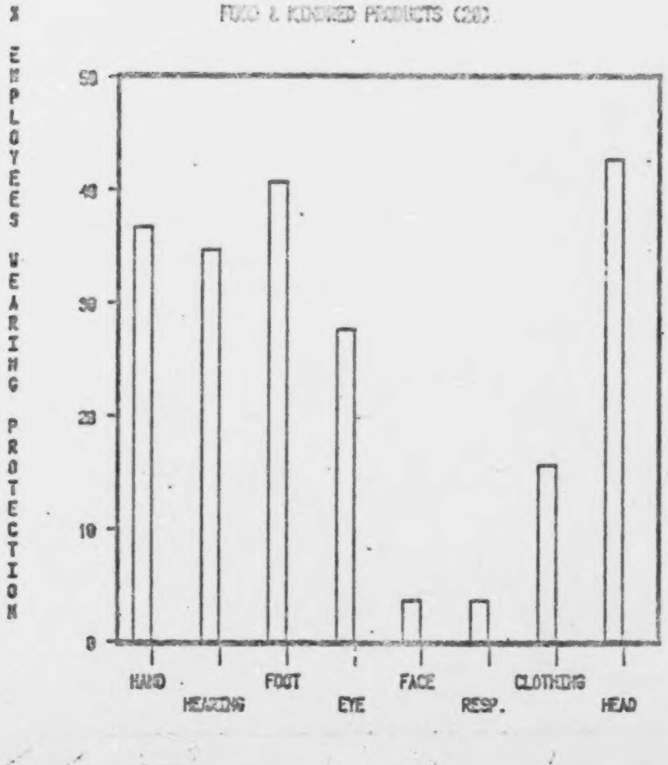


HEAVY CONSTRUCTION CONTRACTORS (18)

EXHIBIT 6-5

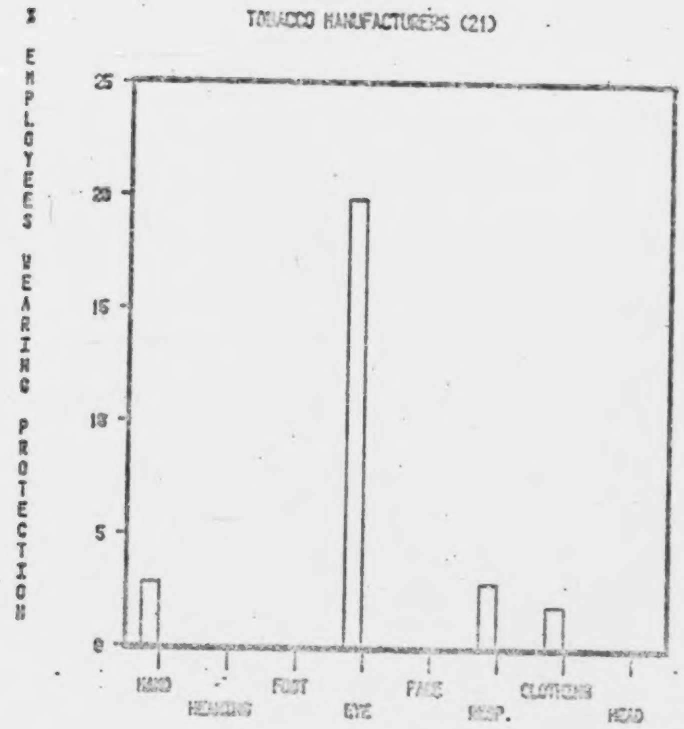


SPECIAL TRADE CONTRACTORS (17)

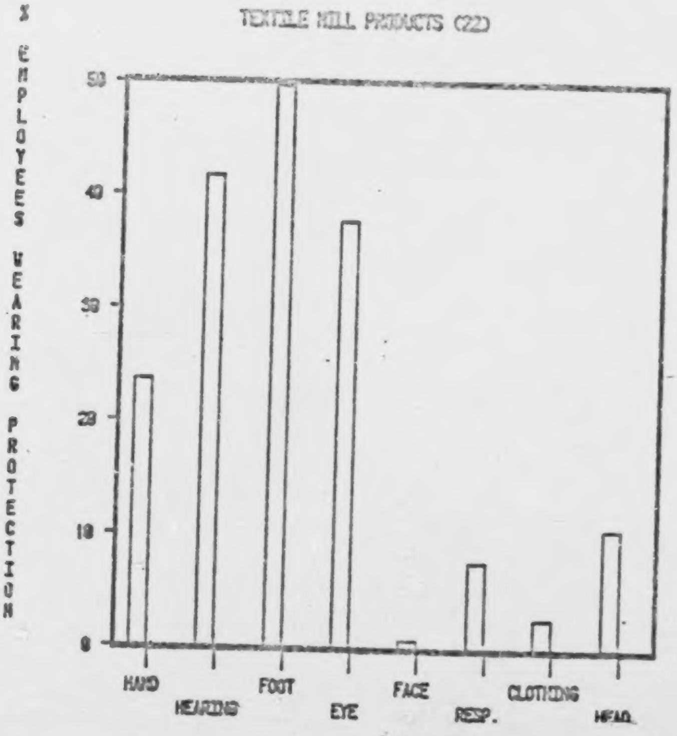


FOOD & KINDRED PRODUCTS (20)

EXHIBIT 6-6



TOBACCO MANUFACTURERS (21)



TEXTILE MILL PRODUCTS (22)

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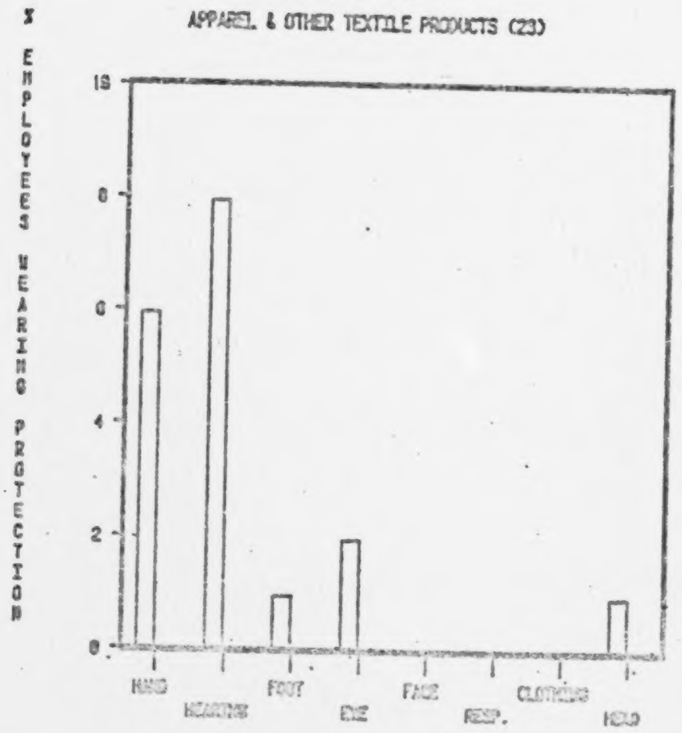
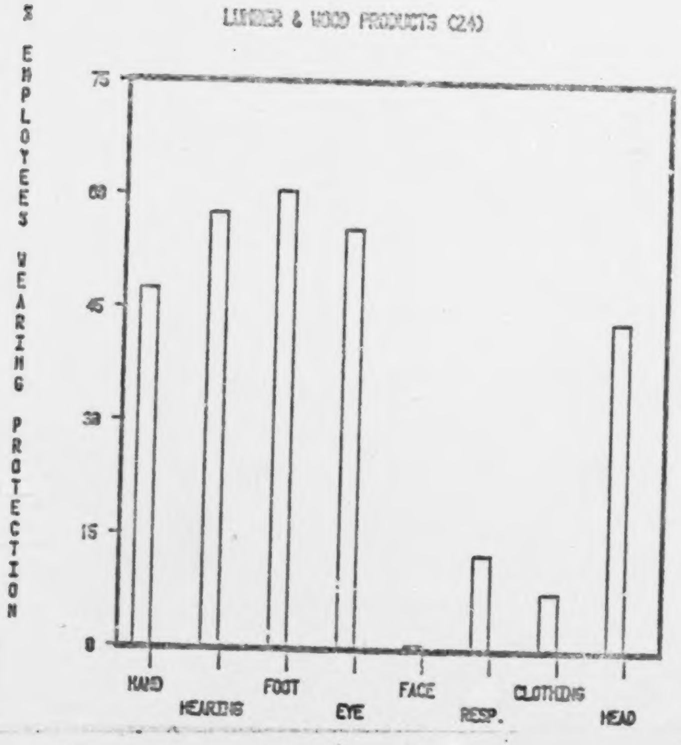
EXHIBIT 6-7



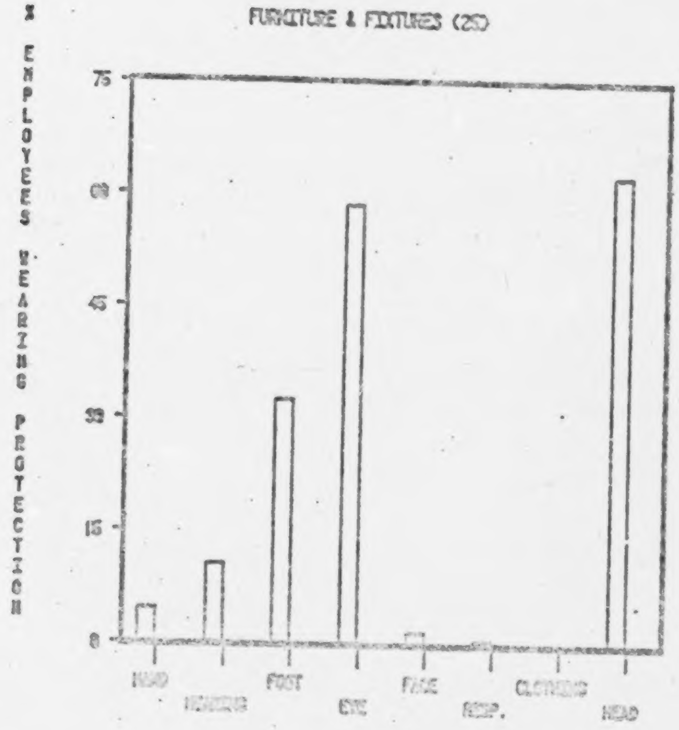
APPAREL & OTHER TEXTILE PRODUCTS (23)



LUMBER & WOOD PRODUCTS (24)

EXHIBIT G-8

FURNITURE & FIXTURES (25)



PAPER & ALLIED PRODUCTS (26)

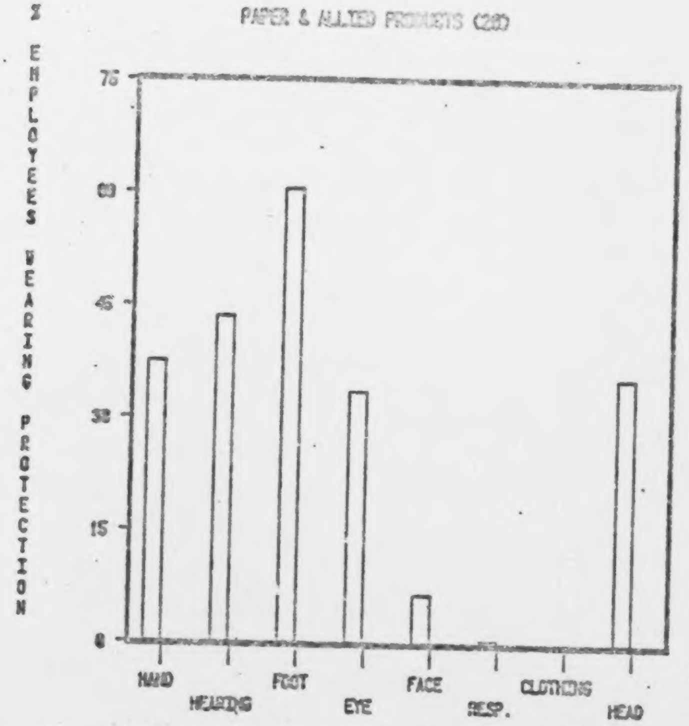
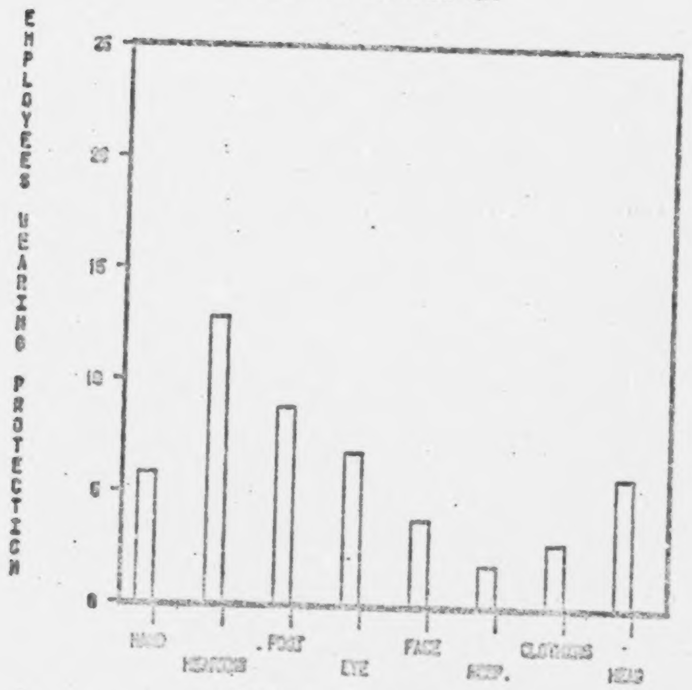


EXHIBIT 6-9

PRINTING & PUBLISHING (27)



CHEMICALS & ALLIED PRODUCTS (28)

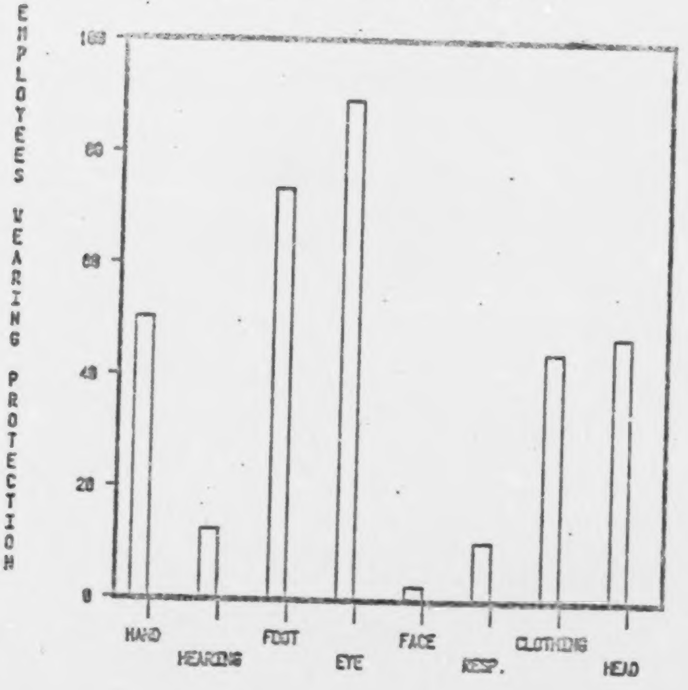
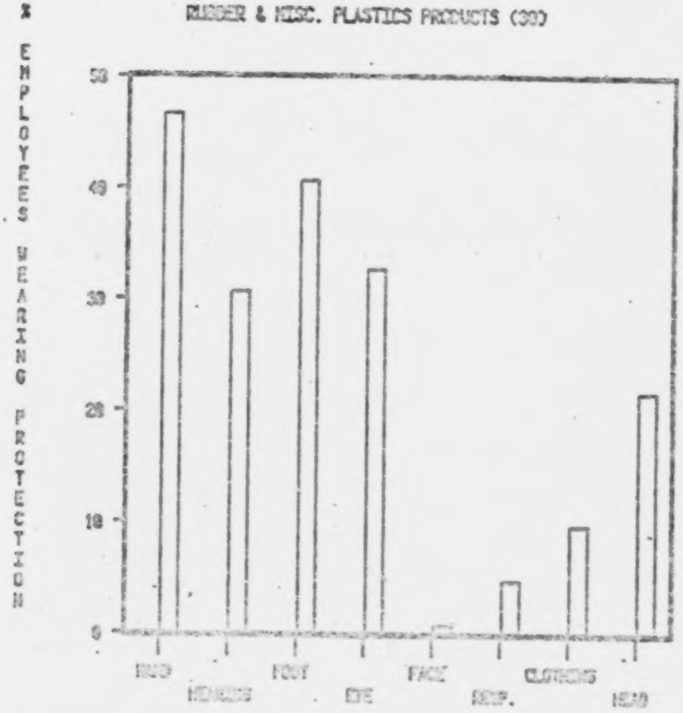


EXHIBIT 6-10

RUBBER & MISC. PLASTICS PRODUCTS (30)



LEATHER & LEATHER PRODUCTS (31)

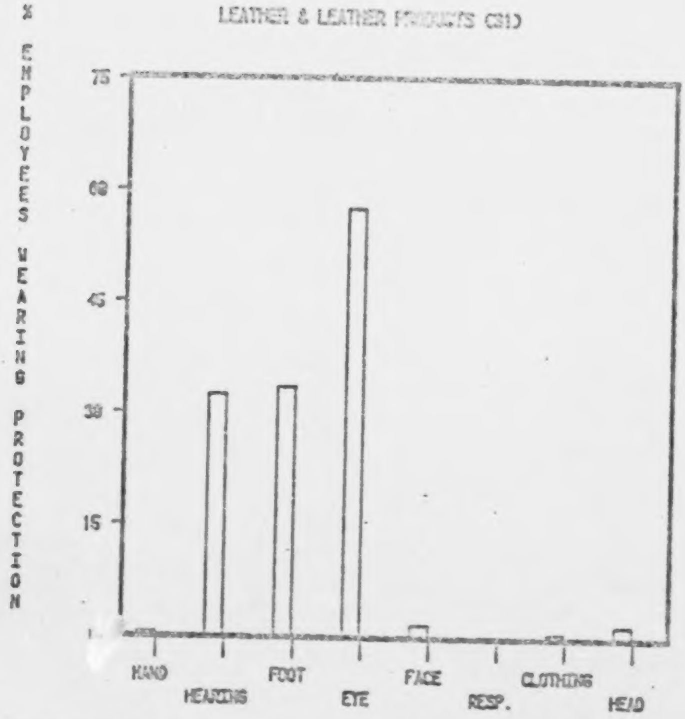


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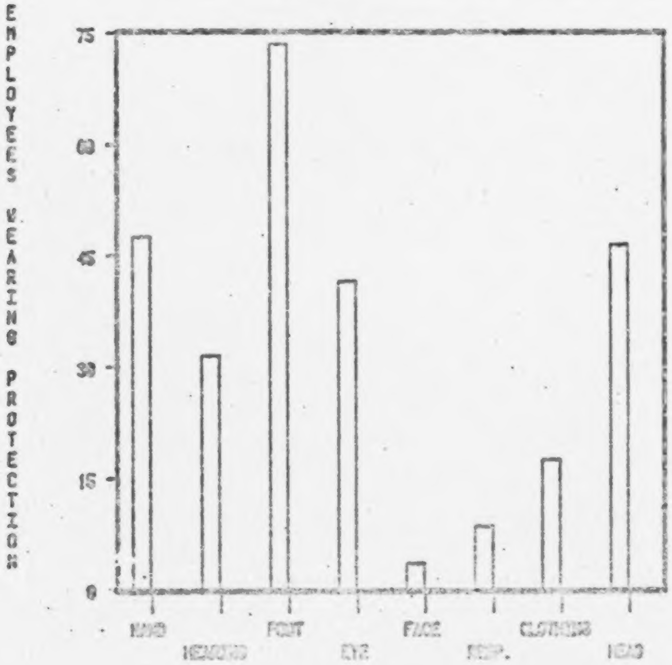
EXHIBIT 6-11

STONE, CLAY & GLASS PRODUCTS (32)



PRIMARY METAL INDUSTRIES (33)

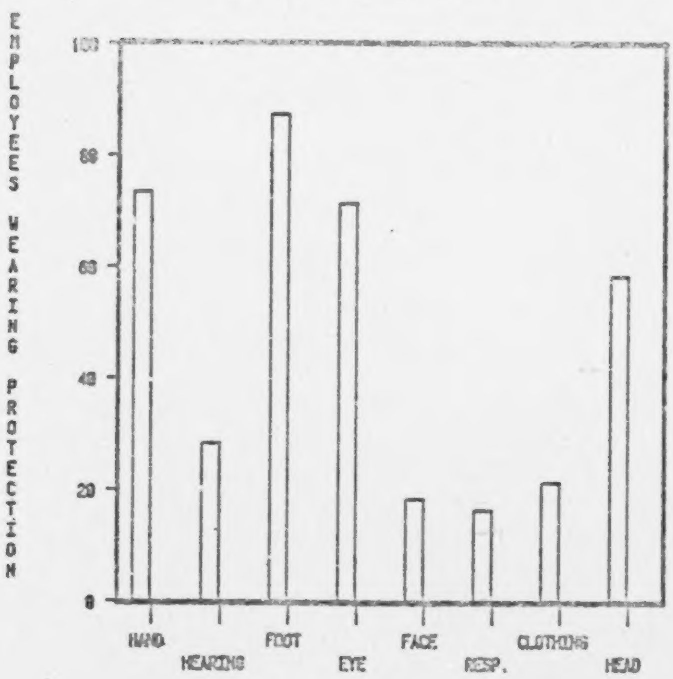
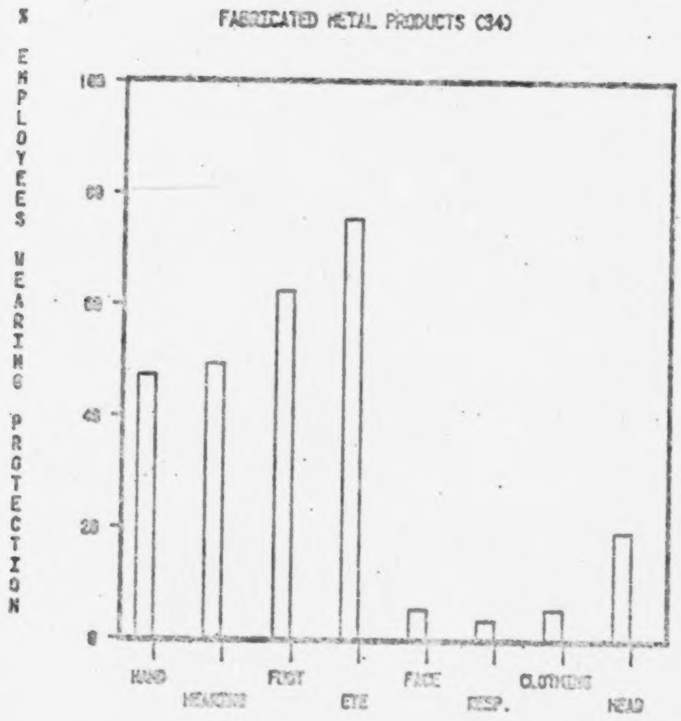


EXHIBIT 6-12

FABRICATED METAL PRODUCTS (34)



MACHINERY, EXCEPT ELECTRICAL (35)

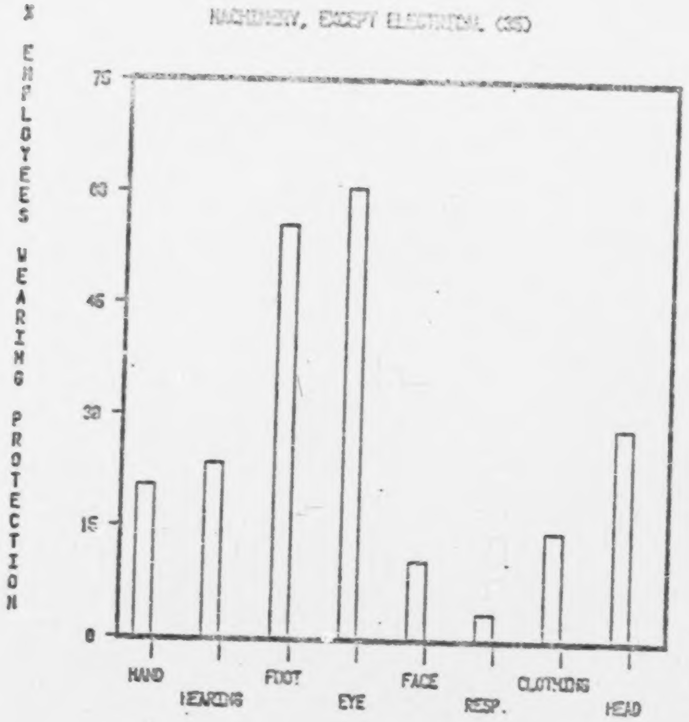
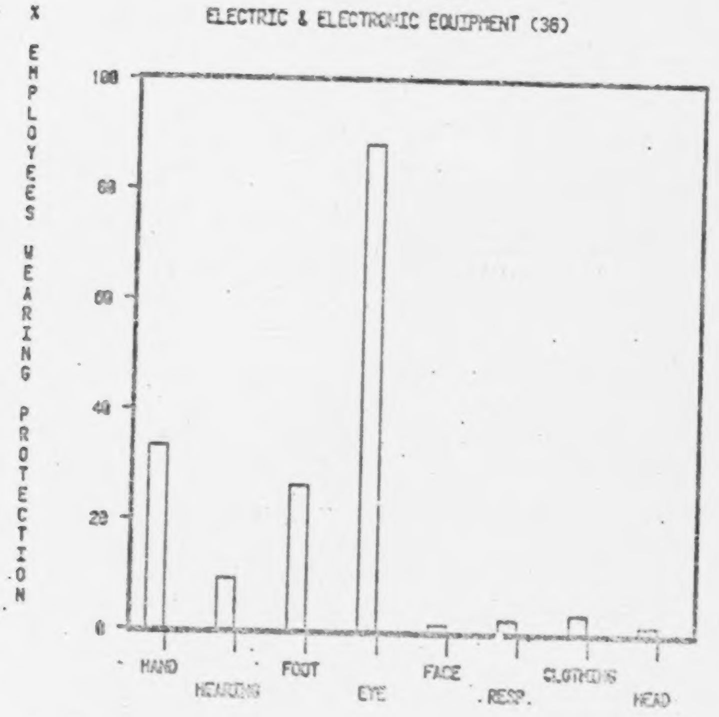


EXHIBIT 6-13

ELECTRIC & ELECTRONIC EQUIPMENT (36)



TRANSPORTATION EQUIPMENT (37)

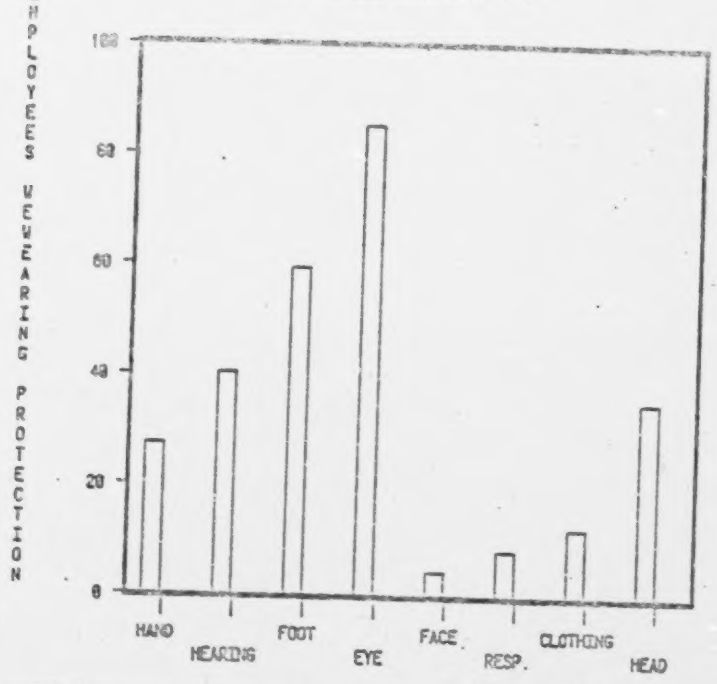
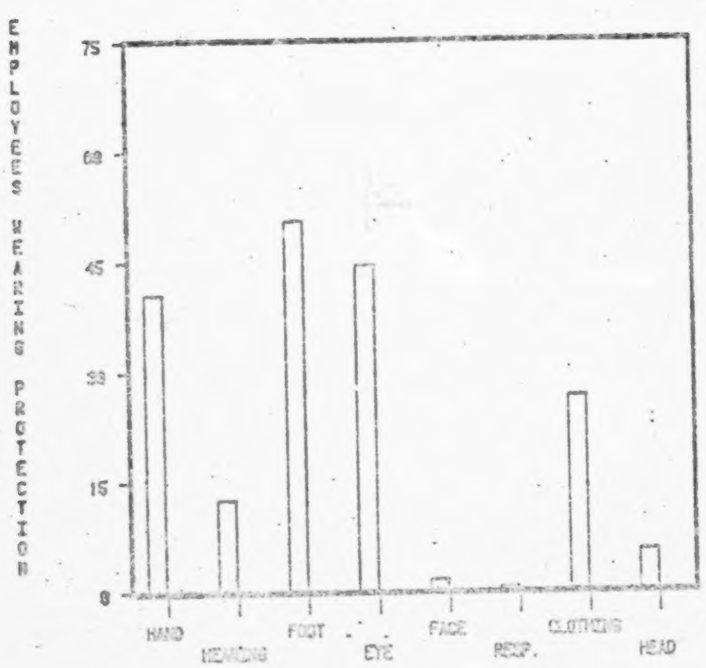


EXHIBIT 6-14

INSTRUMENTS (38)



MISC. MANUFACTURING INDUSTRIES (39)

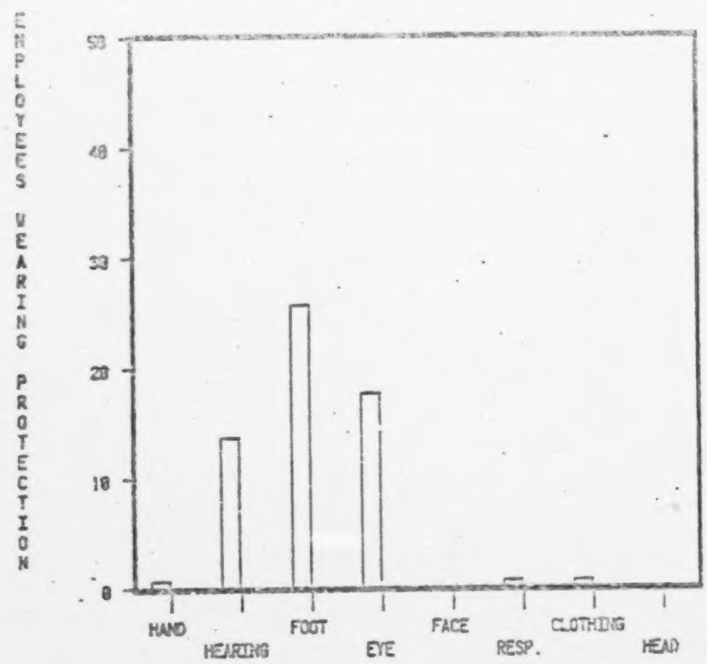
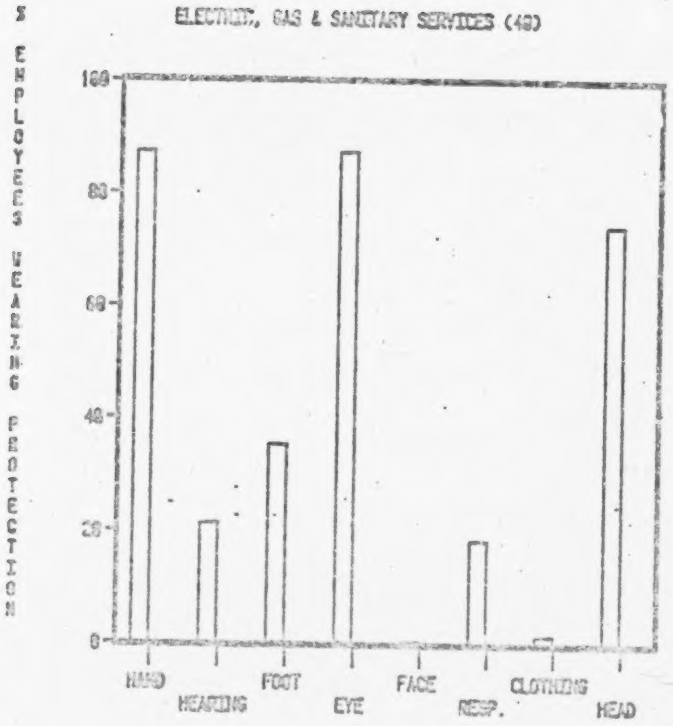


EXHIBIT 6-15


ELECTRIC, GAS & SANITARY SERVICES (49)
% EMPLOYEES WEARING PROTECTION
100
80
60
40
20
0
HAND
HEARING
FOOT
EYE
FACE
RESP.
CLOTHING
HEAD

Two digit SIC code classifications are subdivided into three digit SIC code classifications which are in turn divided into four digit SIC code classifications. Food and kindred products (SIC Code 20) is subdivided into a number of three-digit SIC codes including meat products (SIC Code 201) which is subdivided into a number of four digit SIC codes including sausages and other prepared meats (SIC Code 2013).

The 30 two-digit SIC code industries that are shown in Exhibits 6-1 through 6-15 are comprised of 189 three-digit SIC codes which are comprised of 540 four-digit SIC codes. In the present survey, users in 540 four-digit SIC codes were contacted. The results were tabulated and the average is shown in terms of the two-digit SIC Codes in this section. For a more specific indication of the usage of personal protective equipment and clothing by industry, bar graphs of the average percentage of employees required to wear the equipment by three-digit SIC codes are shown in the Appendix.

Exhibits 6-1 through 6-15 represent an average of the more detailed Appendix. It is advisable to review the graphs in the Appendix since usage can vary within a two digit SIC Code.

Most industries require less than 50% of their employees to wear hand protection. Those industries requiring hand protection for 50% or more of their employees are forestry, masonry, miscellaneous trade contractors, iron ores, miscellaneous metal ores, oil and gas field services, miscellaneous food products, beverages, yarn and thread mill[illegible] mills and planing mills, pulp mills, paper mills, industrial organic and in[illegible] chemicals, plastics, tires and inner tubes, flat glass, pressed or blown glass, blast furnace and basic steel products, iron and steel foundries, primary nonferrous metals, nonferrous rolling and drawing, miscellaneous primary metal products, cutlery, metal forgings and stampings, fabricated structural metal products, medical instruments and supplies, photographic equipment, gas production and distribution and sanitary services.

For hearing protection, usage is usually required for less than 50% of the employees. Industries requiring 50% or more of their employees to wear heaing protection include general building non-residential buildings, highway and street construction, metal mining services, crushed and broken stone, preserved fruits and vegetables, sawmills and planing mills, pulpmills, papermills, tire and inner tubes, cement, metal cans and shipping containers, ship and boat building and repairing, and railroad equipment. Market saturation of protective footwear has reached 100% in the mining industries of metals, non-metallic minerals, and coal and in the building construction industries. Seventy-five percent (75%) or more of the workers in a number of other industries are required to wear protective footwear. These industries are floor covering mills, papermills and paperboard mills, paperboard container and box manufacture, industrial organic and inorganic chemicals, plastics, agricultural chemicals, flat glass, cement, structural clay and pottery, blast furnace and basic steel products, iron and steel foundries, primary non-ferrous metals, nonferrous foundries and miscellaneous metal products, fabricated structural metal products, metal forging and stamping, machinery such as farm construction and metal working machinery, electric distributing equipment, and musical instrument manufacture.

More than 80% of employees are required to wear some type of eye protection in major industries such as metal mining, bituminous coal mining, chemicals and allied products, electrical and electronic machinery, transportation equipment, and the utility service industries of electric, gas, and sewer.

Although less than 15% of the employees in most industries are required to wear face protection, there are a number of industries where usage equals or exceeds 15%. These industries are general building contractors, non-residential building contractors, non-residential buildings, special trade contractors, heavy construction except highway and street construction, gold and silver ores, miscellaneous metal ores, miscellaneous nonmetallic minerals, papermills, cement, nonferrous foundries, iron and steel foundries, primary nonferrous metals, miscellaneous fabricated metal products, metalworking machinery, construction machinery, and ship and boat building and repairing.

In most industries, less than 20% of the employees are required to wear respiratory protection. The industries requiring 20% or more of the employees to wear the equipment are metal mining, general building and special trade contractors, crushed and broken stone quarrying, wool weaving and finishing mills, sawmills and planing mills, industrial inorganic chemicals, cement, blast furnace and basic steel products, primary non-ferrous metals, nonferrous foundries, ship and boat building and repairing, and gas production and distribution.

Market saturation of head protection is nearly 100% for the metal mining, anthracite mining, bituminous coal mining, oil and gas extraction, mineral quarrying, building construction, and general construction industries.

The estimates of the percentage of employees wearing personal protective equipment and clothing shown in Exhibits 6-1 through 6-15 indicate which industries require the greatest percentage of workers to wear the equipment. By multiplying these estimates by the number of total workers in each SIC Code, it is possible to calculate the number of workers wearing the equipment (see Exhibit 6-16). The type of protective equipment worn by more workers is eye protection followed by foot protection, head protection, hand protection, hearing protection, protective clothing, respiratory protection and face protection.

The five industries which require more than one million workers each to wear protective eyewear are electrical and electronic machinery, construction (special trade contractors, transportation equipment, manufacture, machinery manufacture (except electrical) and fabricated metal products. Industries such as construction (general building and special trade), primary metal industries, fabricated metal products, machinery (except electrical) and transportation equipment manufacture each have over one million workers wearing foot protection.

The largest number of workers wearing hand protection is found in SIC Code 17, special trade contractors. Other industries with a considerable number of workers wearing gloves include primary metal industries, fabricated metal products, electric and electronic equipment manufacture, food and kindred products and chemicals and allied products.

The fabricated metal products, transportation equipment manufacture, machinery manufacture, food and kindred products and construction industries have the largest number of workers wearing hearing protection. According to the Occupational Safety and Health Administration, 94% of the production employees in lumber and wood (SIC Code 24) or 648,822 workers, 76% in petroleum and coal (SIC Code 29) or 147,416 workers, 75% in textile (SIC Code 22) or 639,525 workers, 74% in electrical, gas, and sanitary services (SIC Code 49) or 613,978 workers, 63% in primary metals (SIC Code 33) or 720,783 workers, 45% in printing and publishing (SIC Code 27) or 566,235 workers

EXHIBIT 6-13

Total Number of Workers Wearing Protective Equipment

SIC Code	Average Annual Employment	Hand	Hearing	Foot	Eye	Face	Respiratory	Clothing	Head
		# of Employees Wearing the Equipment	# of Employees Wearing the Equipment	# of Employees Wearing the Equipment	# of Employees Wearing the Equipment	# of Employees Wearing the Equipment	# of Employees Wearing the Equipment	# of Employees Wearing the Equipment	# of Employees Wearing the Equipment
10	97,500	46,800	49,725	85,550	67,730	15,600	19,500	21,450	95,550
11	3,400	680	510	3,230	462	303	--	340	3,298
12	244,300	36,645	31,753	244,309	227,160	4,886	14,660	--	244,300
13	552,000	407,860	242,880	331,200	183,150	55,200	60,720	--	540,960
14	122,500	11,025	29,400	122,500	85,750	9,800	15,925	1,225	122,500
15	1,212,000	181,935	545,805	1,212,959	833,923	72,774	169,161	48,918	1,212,000
16	921,800	46,090	443,464	829,800	322,120	131,203	116,616	18,436	912,532
17	2,263,800	2,263,800	452,760	1,131,880	1,697,826	339,505	452,790	63,273	2,263,900
20	1,710,800	632,906	599,780	701,429	670,536	68,432	68,432	372,728	735,644
21	69,200	2,076	--	--	13,640	--	2,076	1,884	--
22	852,700	204,648	358,134	423,353	221,626	8,527	62,216	23,531	93,797
23	1,255,800	75,843	101,284	12,653	25,318	--	--	--	12,358
24	690,300	331,344	400,374	421,003	306,683	6,803	29,730	55,324	333,732
25	468,800	23,440	51,568	154,704	276,502	9,378	4,082	--	295,344
26	694,000	263,720	305,369	433,360	233,960	48,539	6,949	--	249,840
27	1,258,300	75,498	103,570	123,237	88,831	56,382	25,158	27,740	73,493
28	1,107,400	664,774	143,882	819,470	996,869	33,232	121,816	428,339	531,552
30	730,700	343,429	225,617	399,237	361,131	7,397	36,536	75,870	169,754
31	232,600	2,328	76,758	79,024	131,962	4,652	--	2,338	4,552
32	835,600	319,438	212,882	492,544	279,662	28,624	59,904	110,603	312,832
33	1,144,100	848,834	331,738	1,005,603	622,762	217,273	194,497	231,702	675,019
34	1,609,000	772,320	804,300	1,013,870	1,322,940	96,540	64,330	88,549	321,800
35	2,497,000	624,370	699,280	1,398,328	1,523,179	274,079	92,880	374,359	724,130
36	2,163,200	715,082	210,320	887,894	1,871,848	42,084	61,036	84,128	42,064
37	1,875,300	525,084	789,873	1,125,180	1,012,758	22,765	160,777	243,720	675,108
38	703,500	280,465	62,165	331,835	318,625	14,170	7,035	101,393	42,510
39	419,300	4,193	68,703	109,018	75,474	--	4,193	4,193	--
49	829,700	730,136	192,524	289,692	750,108	8,297	157,643	18,534	822,275
		10,238,032	7,482,914	13,473,008	16,193,253	1,610,389	2,026,401	2,425,238	11,275,199

and 26% in paper (SIC Code 26), or 277,600 workers are exposed to noise levels of 85 dB TWA.

The largest number of workers wearing protective clothing are employed in the chemicals and allied products industry. A considerable number of workers wearing protective clothing work in the machinery manufacture, food and kindred products, primary metals and transportation equipment manufacture industries.

Workers employed in construction (special trade contractors), primary metals, transportation equipment manufacture, electric, gas and sanitary services, and the chemicals and allied products industries are the largest users of respiratory protection devices.

For face protection, the industries with the largest number of employees wearing the equipmet are construction (special trade contractors), machinery manufacture, primary metals, and general building construction.

SECTION VII

GOVERNMENT REGULATIONS AND OTHER FACTORS AFFECTING PERSONAL PROTECTIVE EQUIPMENT USAGE

GOVERNMENT REGULATIONS

Government regulation of the workplace began with early legislation at the turn of the century. Massachusetts required the guarding of dangerous machinery to prevent injuries. Workmen's Compensation laws were passed in a number of states, and a Federal law was passed in 1908. At this time, protective equipment such as safety glasses, goggles, shoes, and gloves were being introduced followed by head and respiratory protection.

The passage of the Walsh-Healy Public Contracts Act in 1936 established safety and health requirements for work performed on certain contracts for the federal government. Greater awareness of worker health and safety issues led to the passage of the Coal Mine Health and Safety Act in 1969 and the Occupational Safety and Health Act of 1970. OSHA regulations were promulgated based on voluntary standards of agencies such as the American National Standards Institute (ANSI) and the National Fire Protection Association. When workplace hazards cannot be eliminated by engineering means alone, the use of personal protective equipment and the training of the worker is necessary.

OSHA's General Industry, Construction and Maritime Standards have provisions for the required use of personal protective equipment (see Exhibit 7-1). The required use of personal protective equipment for certain conditions under these categories are shown in Exhibit 7-2. OSHA is planning to revise its respirator standards and is seeking public comments. OSHA's request for comments is accompanied by a listing of questions related to respiratory protection including protection factors, fit testing, employee training, medical screening, costs, respirator testing criteria and the use of powered air purifying respirators.

Subpart 2 of the regulations lists specific hazardous substances and their permissible exposure level. Provisions for respratory protection equipment and other types of equipment are included in the regulations.

EXHIBIT 7-1

OSHA Regulations for Protective Equipment Use

OSHA Regulations	PROTECTIVE EQUIPMENT General Requirements	Head	Eye & Face	Respiratory	Hand	Foot	Clothing
General Industry	1910.132	1910.135	1910.133	1910.134	1910.132	1910.136	1910.132
Construction	1926.28	1926.100	1926.102	1926.103	1910.422	1910.136	1910.1001-.1045
Maritime	1915.57	1910.135	1915.81	1915.82	1910.132	1918.104	1910.132
	1916.57	1926.100	1916.81	1916.82		1915.83d	
	1917.57	1915.31, 83, 155	1917.81	1917.82		1916.83d	
		1916.31, 83, 155	1918.101			1917.83d	
		1918.105					

EXHIBIT 7-2

Personal Protective Equipment Requirements

GENERAL INDUSTRY STANDARDS	Eye & Face	Head	Respiratory	Hand & Arm	Body & Leg	Foot
Section						
Ventilation (abrasive blasting, spray finishing, open surface tanks) (1910.94)	X		X	X	X	X
Storage & Handling of Anhydrous Ammonia (1910.111)			X			
Sanitation (wet processes) (1910.141)						X
Helicopters (1910.183)	X	X		X	X	
Forging Machines (1910.218)	X			X	X	
Mechanical Power Transmission Apparatus (1910.219)					X	
Guarding of Portable Powered Tools (explosive actuated fastening tools) (1910.243)	X					
Welding, Cutting, & Brazing (1910.252)	X	X	X	X	X	
Pulp, Paper, & Paperboard Mills (1910.261)	X	X	X	X	X	X
Textiles (1910.262)	X	X	X	X	X	
Sawmills (1910.265)	X		X	X	X	X
Pulpwood Logging (1910.266)	X	X	X	X		X
Telecommunications (1910.268)	X	X		X	X	
Procedures During Dive (1910.422)				X		
Equipment (for Diving) (1910.430)			X		X	
CONSTRUCTION STANDARDS						
Section						
Gases, Vapors, Fumes, Dusts, & Mists (1926.55)					X	
Working Over or Near Water (1926.106)					X	
Signaling (1926.201)					X	
General Requirements (tools — hand & power) (1926.300)	X					

(Continued)

EXHIBIT 7-2 continued

SPRINGBORN MANAGEMENT SERVICES INC

CONSTRUCTION STANDARDS — CONTINUED	Eye & Face	Head	Respiratory	Hand & Arm	Body & Leg	Foot
Abrasive Wheels & Tools (1926.303)	X					
Ventilation & Protection in Welding, Cutting, & Heating (1926.353)	X		X		X	
Welding, Cutting & Heating in way of Preservative Coatings (1926.354)			X			
General Requirements (electrical) (1926.400)				X		
Battery Rooms & Battery Charging (1926.403)	X			X	X	
Helicopters (1926.551)	X	X			X	
Marine Operations & Equipment (1926.605)					X	
General Protection Requirements (excavations, trenching, & shoring) (1926.650)	X	X	X	X	X	X
Tunnels & Shafts (1926.800)	X		X	X		
General Requirements (power transmission & distribution) (1926.950)				X		
Tools & Protective Equipment (power transmission & distribution) (1926.951)		X		X		
MARITIME STANDARDS						
Section						
Precautions before Entering (1915.11, 1917.11)			X			
Toxic Cleaning Solvents (1915.21; 1916.21)	X		X	X	X	
Chemical Paint & Preservative Removers (1915.22; 1916.22)	X		X	X	X	
Mechanical Paint Removers (1915.23; 1916.23)	X		X	X	X	
Painting (1915.24; 1916.24)	X		X	X	X	X
Ventilation & Protection in Welding, Cutting & Heating (1915.31; 1916.31; 1917.31)	X	X	X		X	
Welding, Cutting & Heating in Way of Preservative Coatings (1915.33; 1916.33; 1917.33)			X			
Guarding of Deck Openings & Edges (1915.43, 1916.43)					X	
Working Surfaces (1915.47; 1916.47; 1917.47)					X	
Health & Sanitation (1915.57; 1916.57; 1917.57)	X					
Abrasive Wheels (1915.74; 1916.74; 1917.74)	X					
Powder Actuated Fastening Tools (1915.75; 1916.75)	X					
Lifesaving Equipment (1915.84; 1916.84; 1917.84)					X	
Hazardous Cargo (1918.86)					X	
Ventilation & Atmospheric Conditions (1918.93)			X			
Longshoring Operations in the Vicinity of Repair & Maintenance Work (1918.95)	X					
First Aid & Life Saving Equipment (1918.96)					X	
Protection Against Drowning (1918.106)					X	

Source: Best's Safety Directory - 1982

Hearing protection is addressed in Section 1910.95. OSHA issued a final rule on the hearing conservation amendment on January 16, 1981. The rule requires the availability of hearing protection for workers exposed to noise levels of 85 dB TWA or greater. Wearing of hearing protectors is mandatory for workers exposed to noise levels of 90 dB TWA or greater and for those employees with detected hearing losses who are exposed to a TWA of 85 dB.

FACTORS IMPACTING THE USE/NON-USE OF THE EQUIPMENT

A number of equipment users, distributors and manufacturers were surveyed to determine the factor that had the greatest impact on the use/non-use of personal protective equipment. There appears to be no clear consensus on which factor most greatly affects whether the worker does or does not use the equipment. The large number of respondents stated that the primary factor was comfort. A number of companies stated that equipment is selected which the employee considers the most comfortable and the most acceptable. An equal number of respondents considered enforcement by the company to have the greatest impact on the users of personal protective equipment. A number of safety directors commented that wearing of the equipment was a condition of employment with the supervisor monitoring the usage of the equipment.

The worker's attitude on safety or the perceived need for the equipment on the part of the worker is another factor affecting use of the equipment. A number of respondents stated that the most important factor is educating the employee about the hazards present and then the worker will be more agreeable about wearing the equipment.

SECTION VIII

TRENDS IN THE PERSONAL PROTECTIVE EQUIPMENT AND CLOTHING INDUSTRY AND FUTURE OUTLOOK

GROWTH TRENDS IN THE 1970s

Statistics which have been compiled on the usage of protective equipment in the past two decades have been minimal. The Bureau of the Census estimates the value of shipments of protective equipment every five years which limits the ability to establish trends in the usage of protective equipment. More detailed information is compiled on a yearly basis for footwear and gloves.

The overall market for footwear increased at an annual rate of 2% in the 1970s with the penetration of imported footwear gaining 30% in 1970 compared with 53% in 1979. The increased share of imports has resulted in a decline in U.S. production of consumer and industrial work shoes of 1.5%/year. The statistics show an increase in plastic protective footwear.

U.S. shipments of gloves fluctuated during the 1970s with growth limited to 1.9% in the nine-year period from 1970 to 1979 before its decline to the present level. Since the volume of imports was not reported, demand for hand protection in the 1970s cannot actually be determined. However, no growth in hand protection is expected at the present time.

The only available statistics providing trends on usage of personal protective equipment and clothing in the past two decades are shown in Exhibits 8-1 and 8-2. According to the information provided in Exhibit 8-1, growth was experienced in the respiratory protection segment with a small decline in eye and face protection. Overall growth in personal protective equipment was 4.99% for the period of 1972 - 1977. The market for personal protective equipment exceeded $400 million in 1977.

EXHIBIT 8-1

Value of Shipments of Personal Protective Equipment and Clothing in 1972 and 1977

	Current Dollars		Constant Dollars		
	Millions of $ 1977	1972	Millions of $ 1977	1972	% Difference
Personal industrial safety devices SIC Code 38423	403.1	226.0	288.3	226.0	4.99
- Respiratory protection equipment, including gas masks, abrasive masks, canister masks, etc.	127.5	56.5	91.2	56.5	10.05
- Eye and face protection devices including face shields, hoods, and welding helmets and masks but excluding industrial goggles and eye protectors	44.1	37.8	31.54	37.8	-3.55
- Protective clothing, except shoes	68.4	48.4	48.93	48.4	.22
- Other personal safety devices	119.6	65.8	85.55	65.8	5.39
- Personal industrial safety devices not otherwise classified	19.9	6.6	14.23	6.6	16.62
Industrial goggles, eye protectors, welding circles and plates, mounting and parts SIC Code 38513	48.5	36.6	34.69	36.6	-1.06

Source: Bureau of the Census

EXHIBIT 8-2

Market for Personal Protective Equipment
and Clothing for 1963 and 1976

	Current Dollars		Constant Dollars	
	Millions of Dollars		Millions of Dollars	
	1963	1976	1963	1976
Foot	97	214	97	133
Eye & Face Protection	48	95	48	59
Head Protection	23	74	23	46
Clothing	22	72	22	45
Respiratory Devices	34	65	34	41
Ear	2	38	2	24

Source: Predicasts

THE CURRENT MARKET FOR PROTECTIVE EQUIPMENT AND CLOTHING

Prior to a discussion of future trends for personal protective equipment and clothing, the current market for the equipment will be summarized. Exhibit 8-3 provides estimates of the 1981 consumption for each segment of the personal protective equipment market and the percentage of the total market that each segment comprises. The largest segments of the protective equipment market are hand protection, foot protection and protective clothing.

EXHIBIT 8-3

The 1981 Market for Personal Protective Equipment

	Million $	% of Total Market
Hand Protection	790	37
Foot Protection	503	23
Protective Clothing	315	15
Respiratory Protection	272	13
Eye Protection (including goggles, plano eyewear and prescription eyewear)	149	7
Face Protection (including faceshields and welding helmets)	55	2
Hearing Protection	37	2
Head Protection	28	1
Total	2,149	100

FUTURE GROWTH OF PROTECTIVE EQUIPMENT AND CLOTHING

Future growth of protective equipment is expected parallel that of the workforce for most segments of the personal protective equipment and clothing market. Compared with the 1970s, the workforce will grow at a slower pace in the next decade. From 1980 to 1990 civilian employment is projected to increase at 1.5% compared with 2.35% for the 1970s. Non-agricultural employment is forecasted to grow at only 1.6% compared to 2.67% for the previous decade. Growth in the blue collar workforce will be limited to 1.2% compared with previous growth of 1.6%

Projected growth of personal protective equipment and clothing over the next five years is shown in Exhibit 8-4.

EXHIBIT 8-4

Projected Consumption of Personal Protective Equipment and Clothing in 1986 in Constant 1981 Dollars

	Million $	Average Annual Growth Rate (%) 1982-1986
Hand Protection	868.0	1.9
Foot Protection	583.1	3.0
Protective Clothing	411.7	5.5
Respiratory Protection	364.0	6.0
Eye Protection	156.6	1.0
Hearing Protection	66.7	12.5
Face Protection	57.8	1.0
Head Protection	30.3	1.6
Total	2,538.2	3.4

SECTION IX

IMPROVEMENTS IN PERSONAL PROTECTIVE EQUIPMENT AND CLOTHING

USERS' CRITICISMS OF RESPIRATORS

Users of respiratory protection devices in over 30 SIC codes were asked to comment on their satisfaction or dissatisfaction with respirators and laminar flow helmets. The vast majority were unfamiliar with the term "laminar flow helmet." A few described a laminar flow helmet as a device that provides a constant flow of air at positive pressure.

The user will generally notify the respirator manufacturers of any complaints with the device by informing the individual from whom the unit was purchased. In most cases, that individual is the distributor of the equipment. Some users inform the manufacturer's sales representative of the problem either personally during a regular visit, by telephone, or through written communication depending on the severity of the problem.

If satisfactory results are not obtained through the distibutor, the user may contact the manufacturer directly. Some users do not voice their dissatisfaction but simply do not purchase the product again. Most users stated that they had no complaints about respirators. A few users expressed a dissatisfaction with the comfort of the respirators but have no complaints related to performance. This problem is partially being corrected with the development of respirators with different size facepieces for different facial configurations. Some respirators may be ill fitting on workers wearing glasses or having beards. One drawback of atmosphere supplying respirators is the time required to set them up for use, e.g. connecting hoses. Another comment related to the need for a single element capable of filtering out more contaminants to minimize the number of times that the cartridge must be changed.

Some units are described as hot, bulky and too heavy to wear. These complaints probably related to self-contained breathing apparatus (SCBA). Although SCBA are classified as respiratory protection, the term respirator does not actually apply to these units so that some users when asked to describe problems encountered with respirators may not have included SCBA in the discussion.

Criticisms of current respirators that were enumerated by equipment manufacturers were concerned with the cost of the units, availability of parts, the weight of the units, that the units were hot to wear, increased breathing resistance and complaints related to personal preference, e.g. color, hose length, belt length, padded shoulder strap, etc. Certain powered air purifying respirators were described by one distributor as having battery packs that do not allow for many recharges. The manufacturer of the powered air purifying devices believes that the majority of complaints received may be attributed to user misuse or lack of proper education in using the equipment, i.e., shorting out the battery, wearing the visor up, improper maintenance of the respirator allowing the entrance of dirt.

No manufacturer contected claimed to offer a laminer flow helmet. As described by one manufacturer, laminer flow helmets may be defined as respirators having air that flows in parallel lines so that no turbulence exist. The term could not be applied to their powered air purifying respirators since no testing has been performed to establish the lack of turbulence.

Certified equipment that has been determined to be defective has been recalled by NIOSH. The Institute proposed to decertify a certain MSA powered air purifying respirator and is continuing field tests to evaluate the protection provided by the units. Decertification proceedings were dismissed on the basis of lack of proof, although NIOSH was not required to retract its statement. The United Steelworkers of America had requested that the units not be used especially when the contaminant exceeds ten times the permissible standard because the Union found the filter to be loose-fitting. Use of the Racal AH-3 was also discouraged while use of other belt-mounted powered respirators similar to the MSA respirators were considered acceptable.

CURRENT RESEARCH AND DEVELOPMENT IN RESPIRATORS

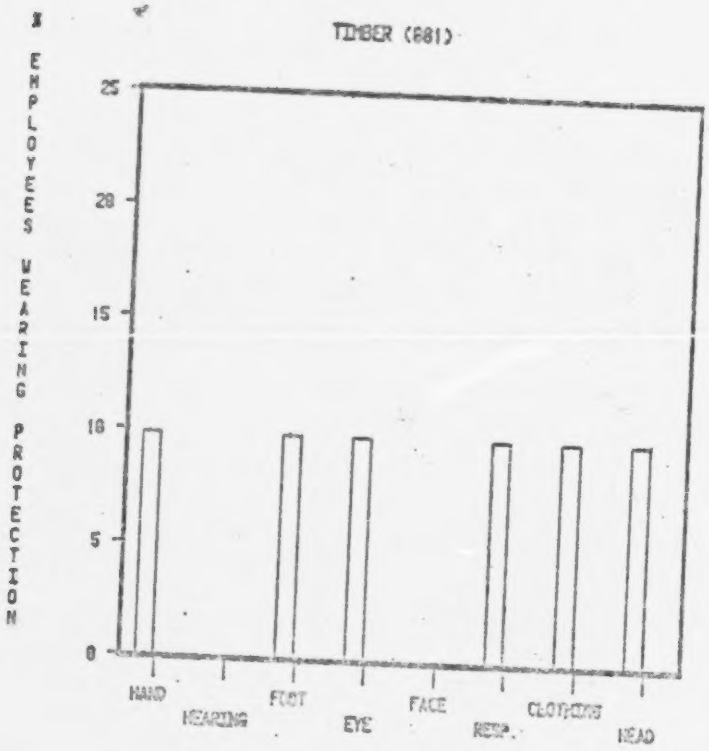
Regulations detailed in 30 CFR Part 11 specify equipment designs that NIOSH may certify. A revision of the regulations is expected to be issued, possibly next year. Some manufacturers believe that NIOSH may impede respirator research and development because a totally new product may not fit into categories defined in 30 CFR, e.g., mercury vapor respirators are approved for dust and mists but not for mercury vapor. For closed circuit positive pressure SCBA a test does not exist so that the test for closed circuit negative pressure SCBA must be used. Others consider these comments to be an exaggeration as greatly impeding respirator research and development. The NIOSH testing program was also criticized as being inadequate, time consuming and not obtaining results that equal the manufacturers.

Current research and development that was described by equipment manufacturers included more comfortable designs, more comfortable, lightweight material such as silicone, high efficiency filters, the closed circuit rebreather technology, the loaded web technique in the manufacture of disposable masks, longer duration SCBA, lighter weight units, a broadened range of applications of the cartridge, the pre-filter which lengthens the life of the filter and different size facepieces for full facepiece respirators.

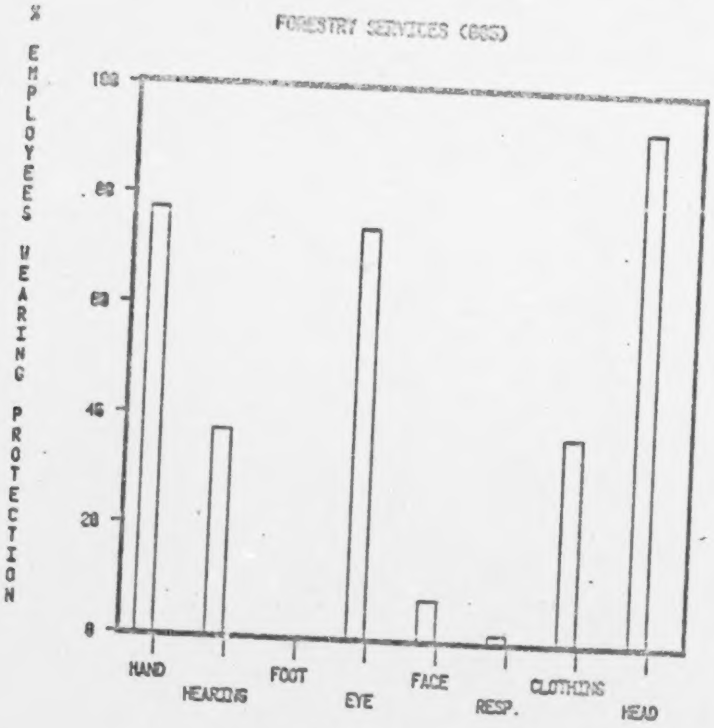
Although the research and development is conducted on the manufacturers own initiative, it is based on identified needs in the market often from user suggestions, the introduction of new standards, and developments in the industry and the manufacturer's desire to remain competitive.

APPENDIX

A-1

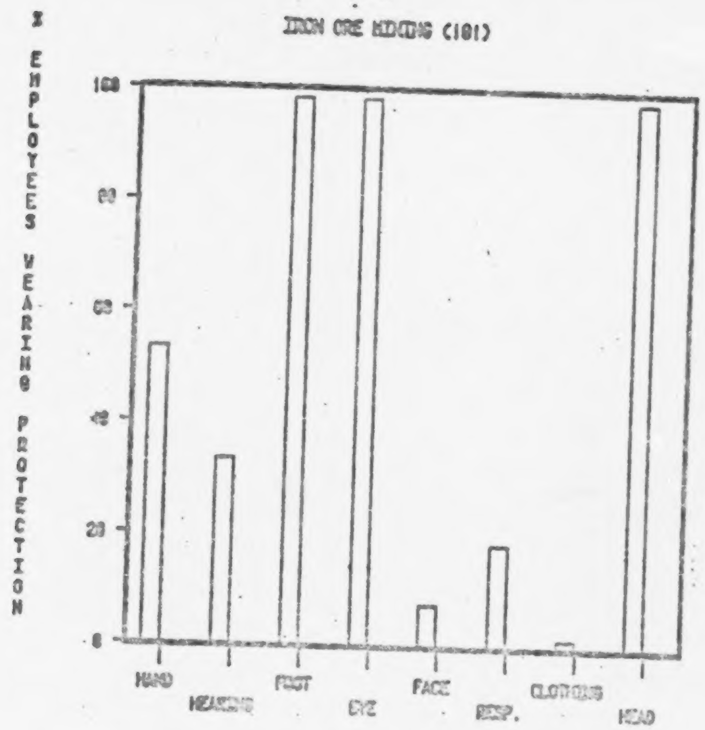


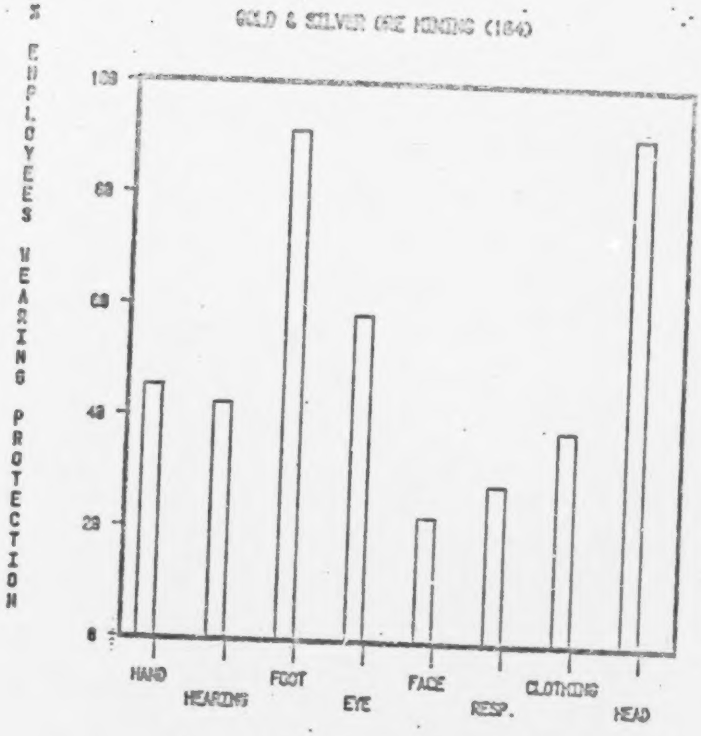
TIMBER (081)



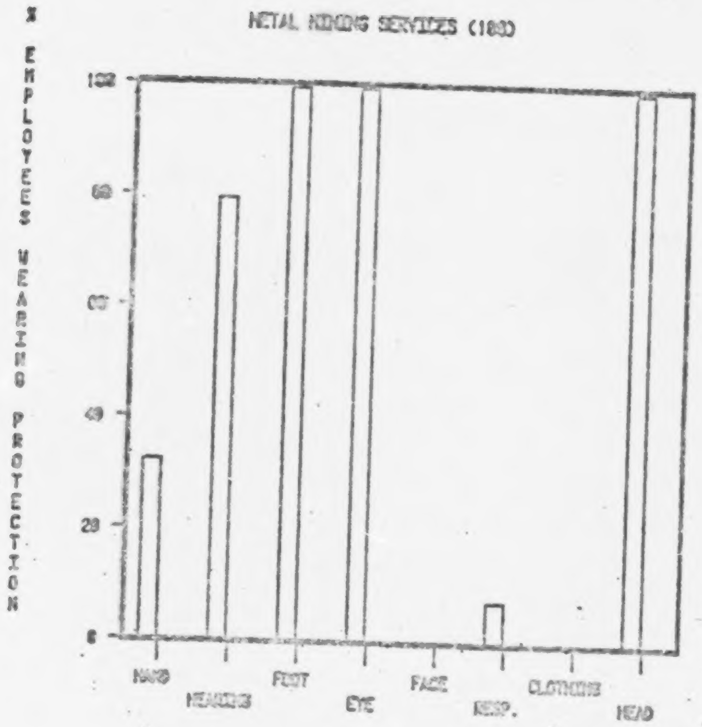
FORESTRY SERVICES (085)

A-2

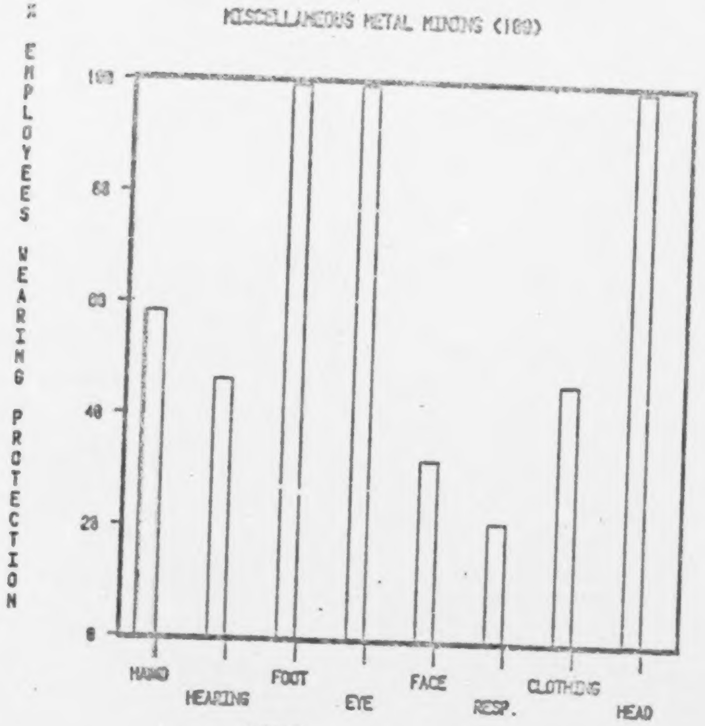

IRON ORE MINING (101)

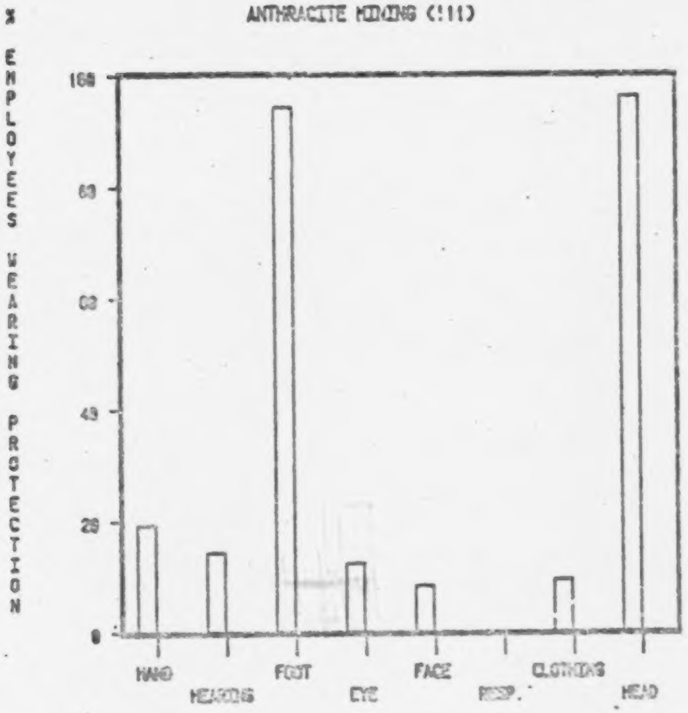

GOLD & SILVER ORE MINING (104)

METAL MINING SERVICES (108)

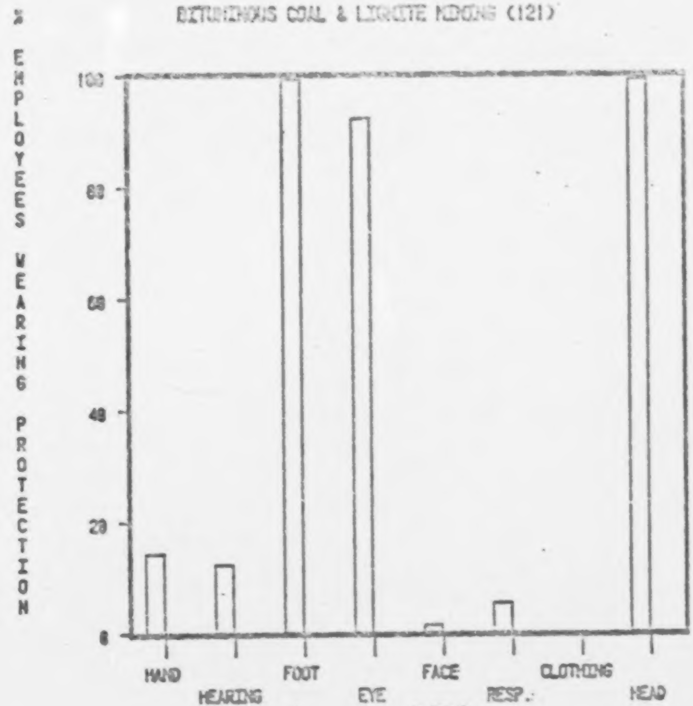


MISCELLANEOUS METAL MINING (109)

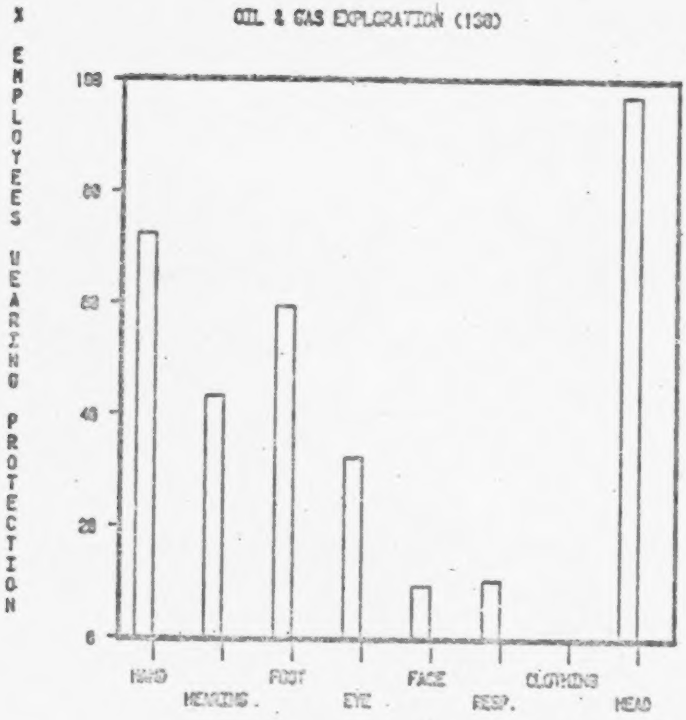


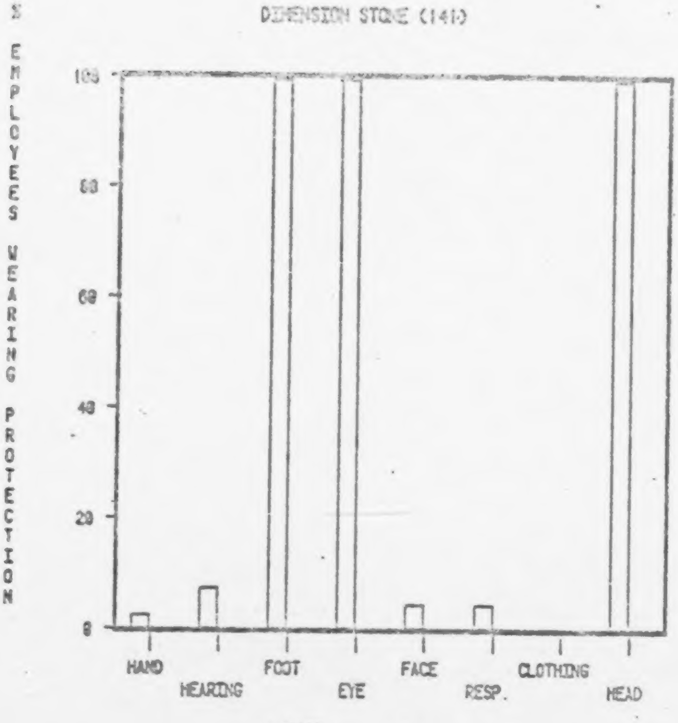


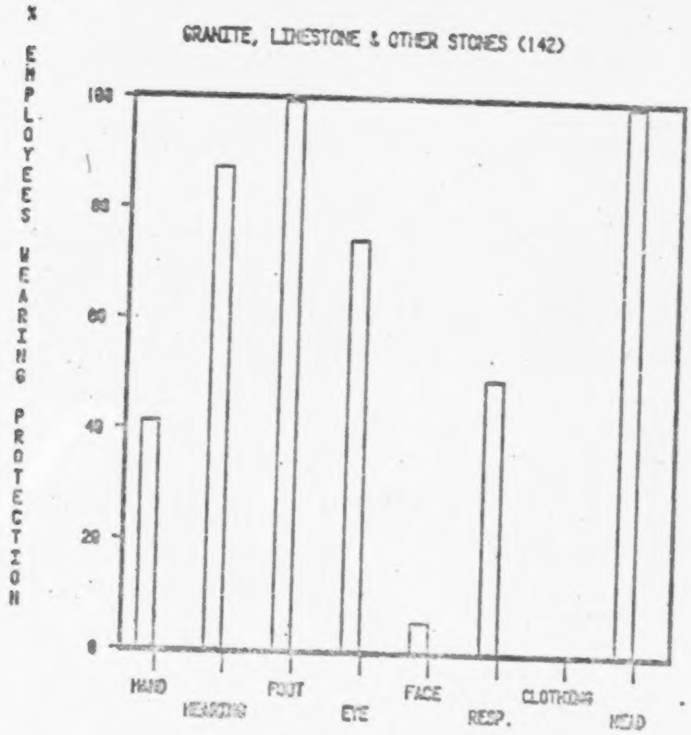
ANTHRACITE MINING (111)



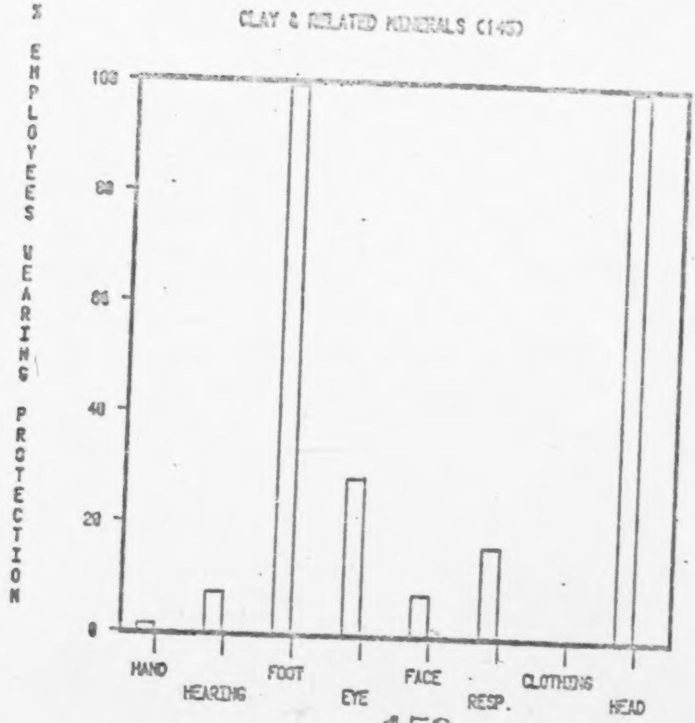
BITUMINOUS COAL & LIGNITE MINING (121)


OIL & GAS EXPLORATION (130)

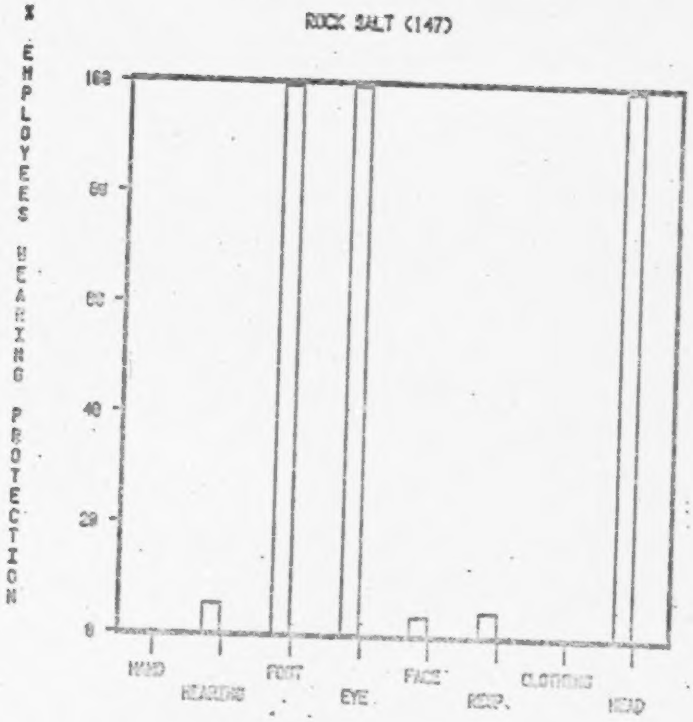

DIMENSION STONE (141)



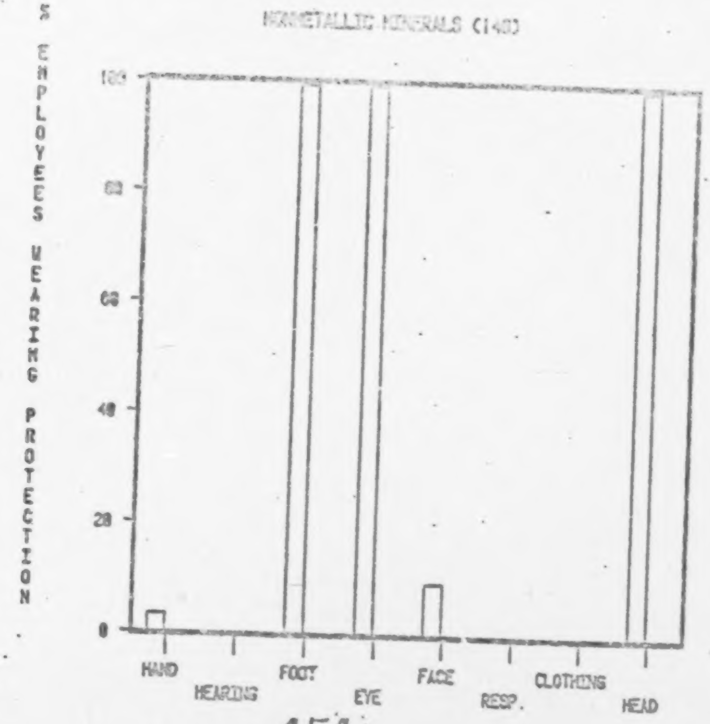
GRANITE, LIMESTONE & OTHER STONES (142)



CLAY & RELATED MINERALS (145)

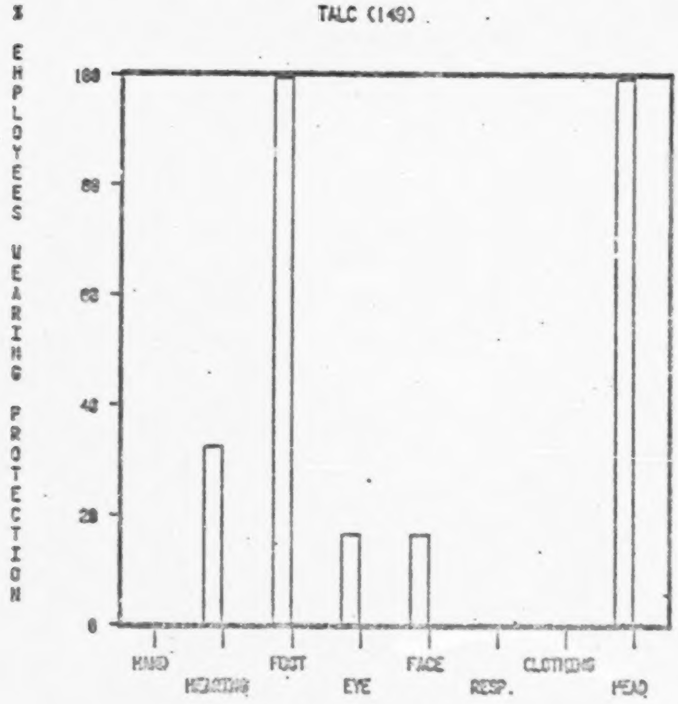


ROCK SALT (147)

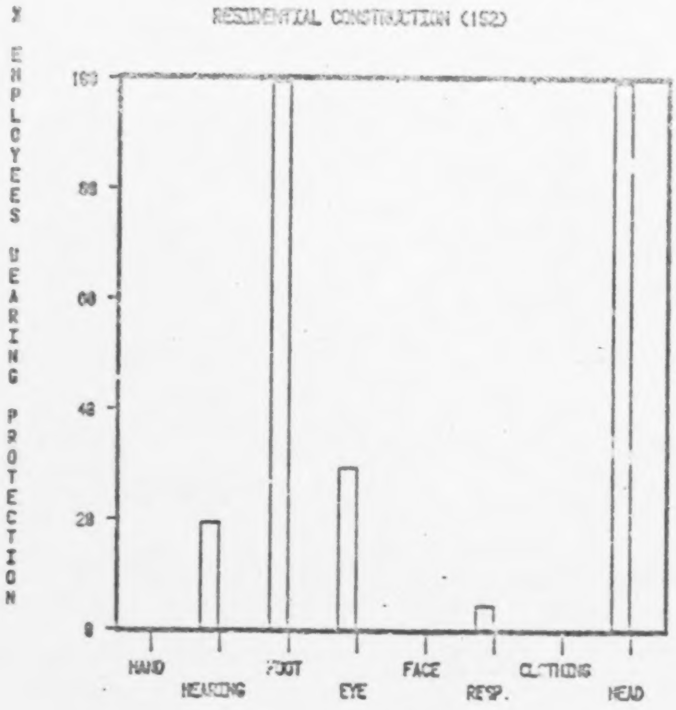


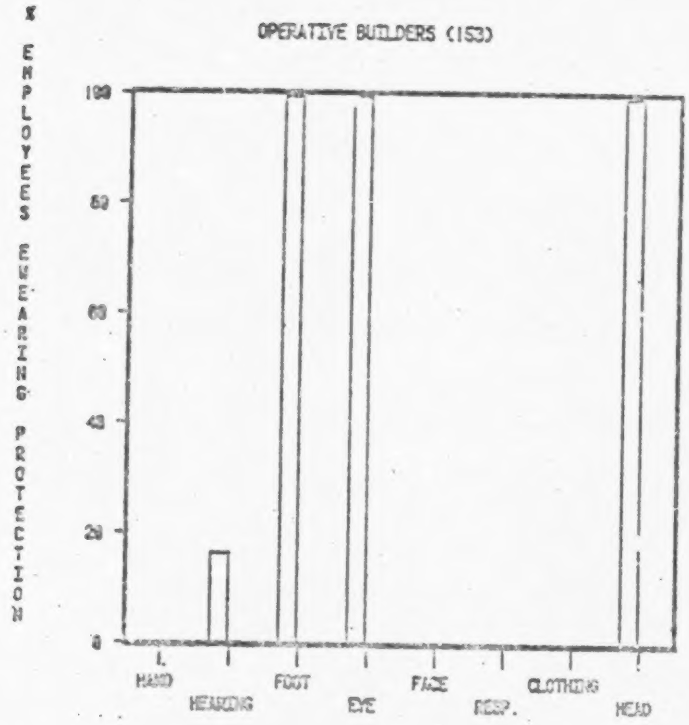
NONMETALLIC MINERALS (148)

TALC (149)

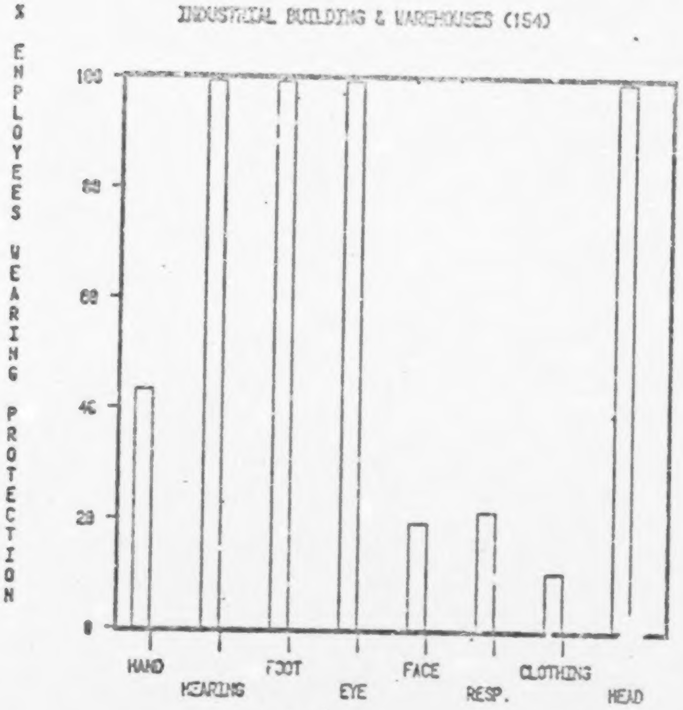


RESIDENTIAL CONSTRUCTION (152)

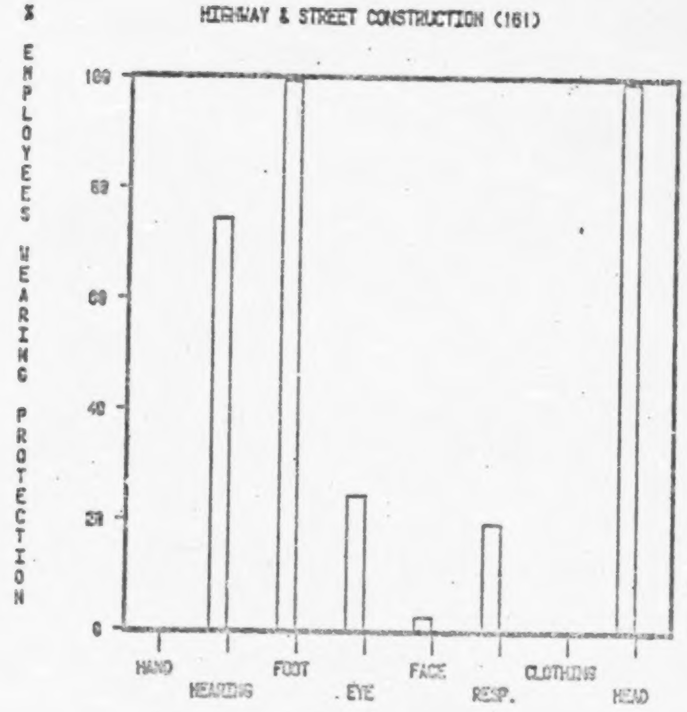


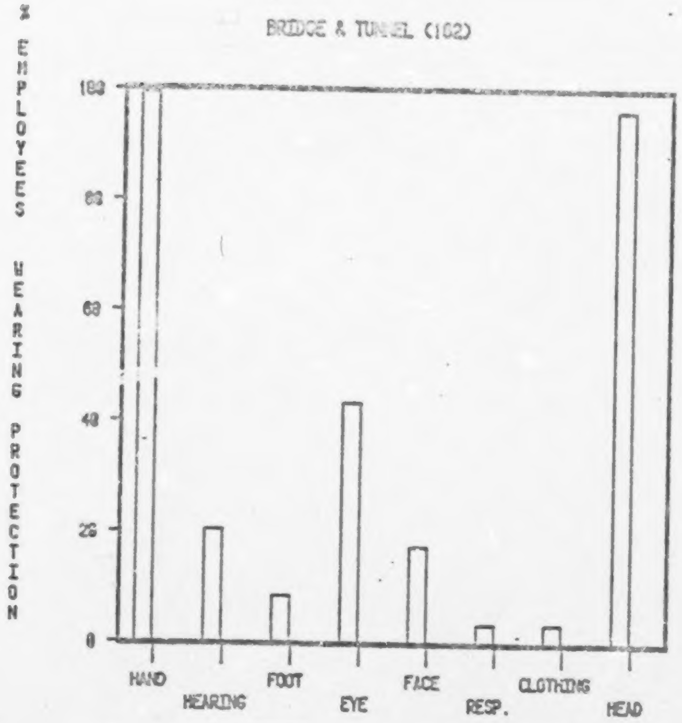


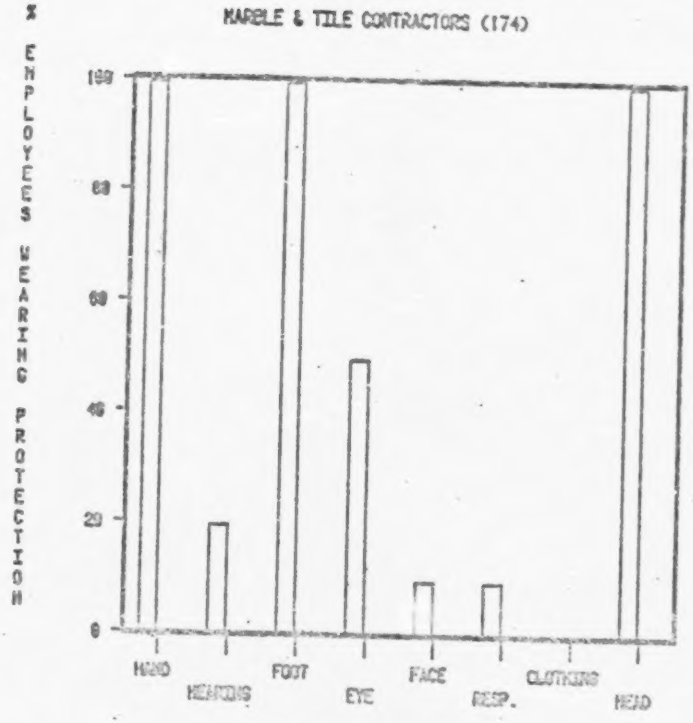
OPERATIVE BUILDERS (153)

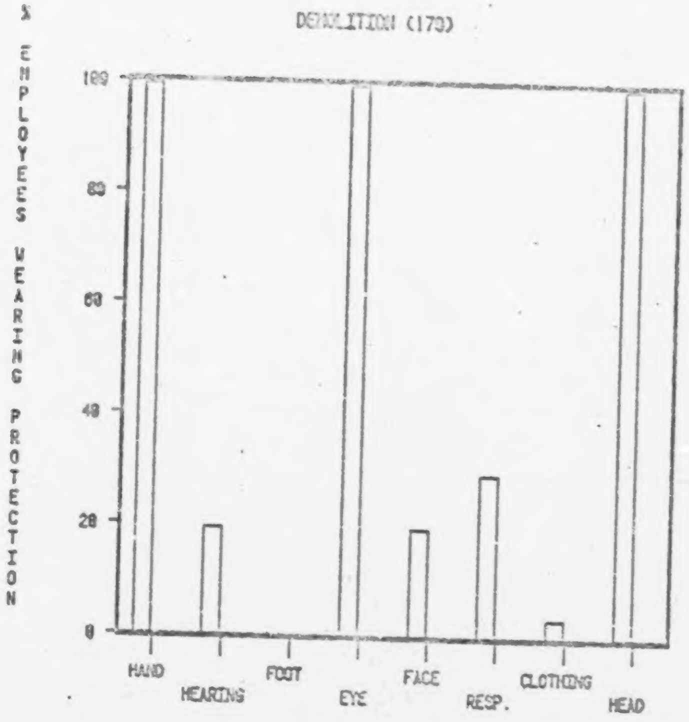


INDUSTRIAL BUILDING & WAREHOUSES (154)


HIGHWAY & STREET CONSTRUCTION (161)


BRIDGE & TUNNEL (162)


MARBLE & TILE CONTRACTORS (174)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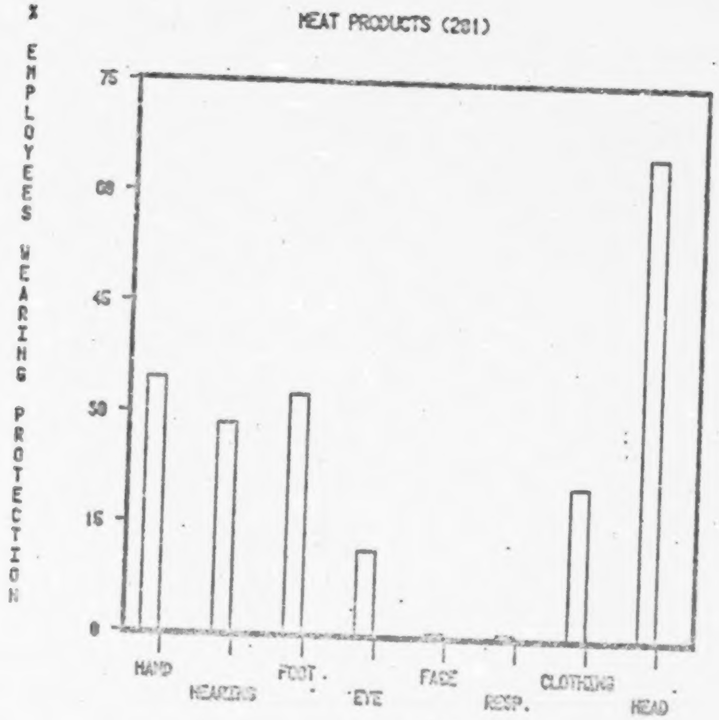
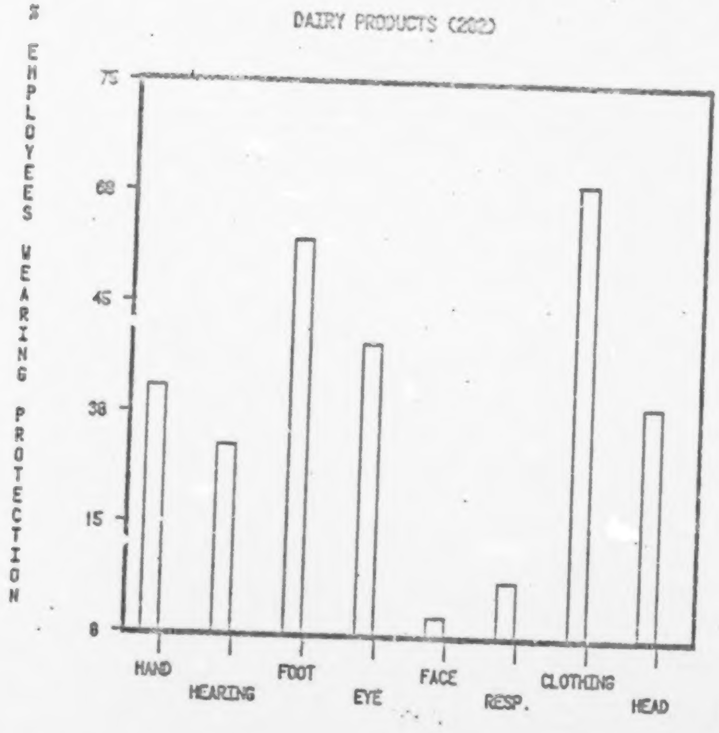
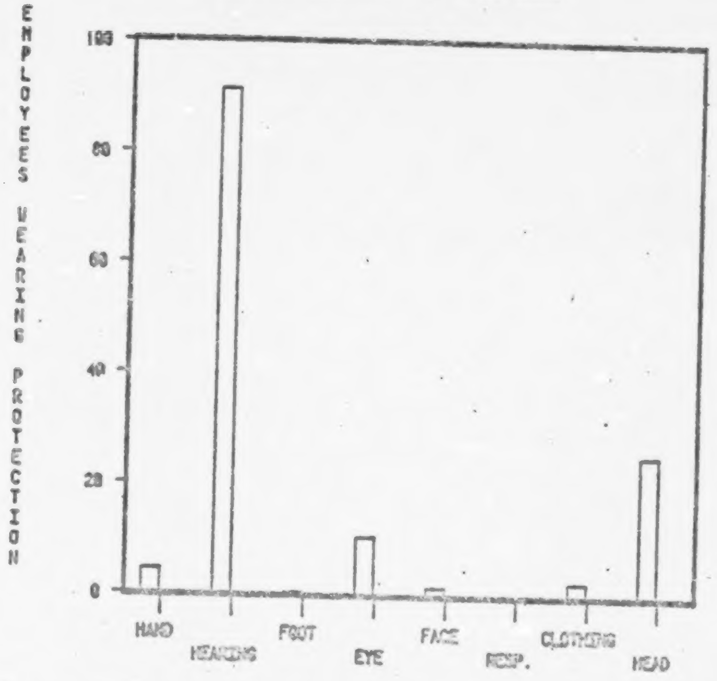
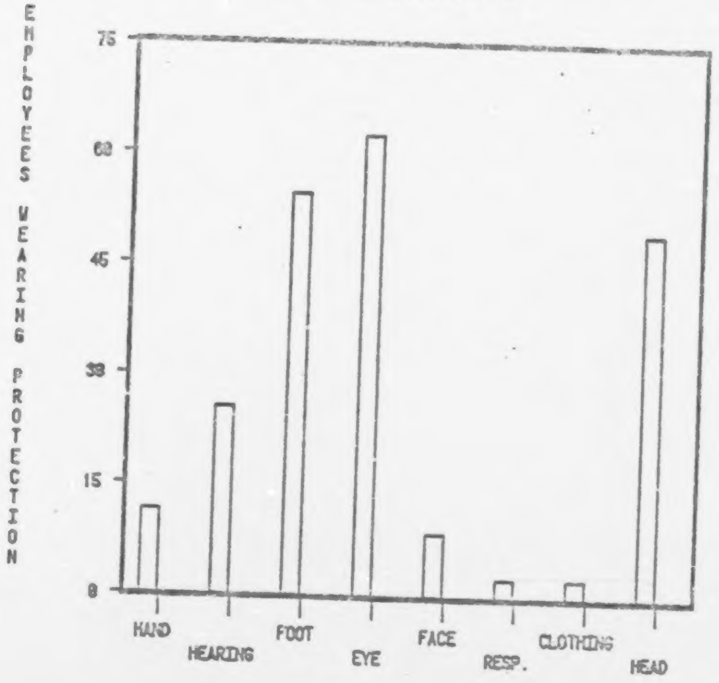

MEAT PRODUCTS (201)
% EMPLOYEES WEARING PROTECTION
75
60
45
30
15
0
HAND
HEARING
FOOT
EYE
FACE
RESP.
CLOTHING
HEAD

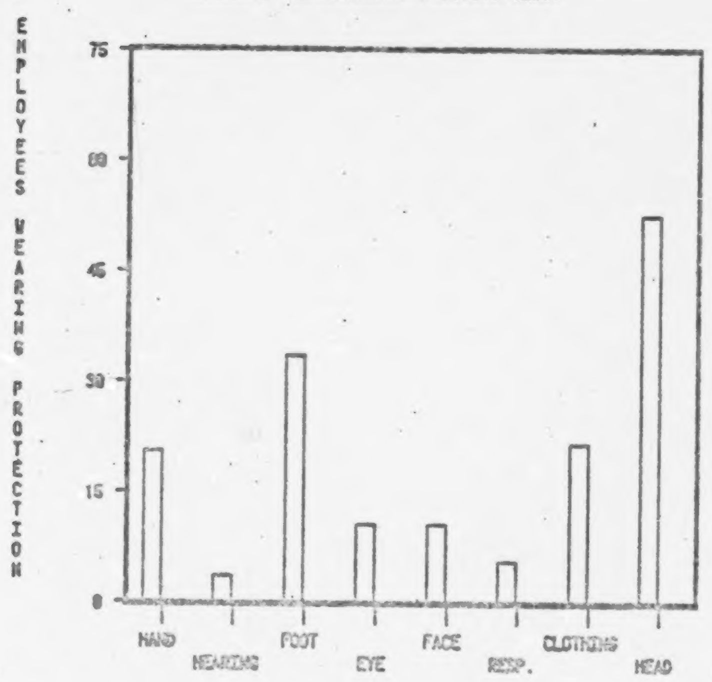

DAIRY PRODUCTS (202)
% EMPLOYEES WEARING PROTECTION
75
60
45
30
15
0
HAND
HEARING
FOOT
EYE
FACE
RESP.
CLOTHING
HEAD



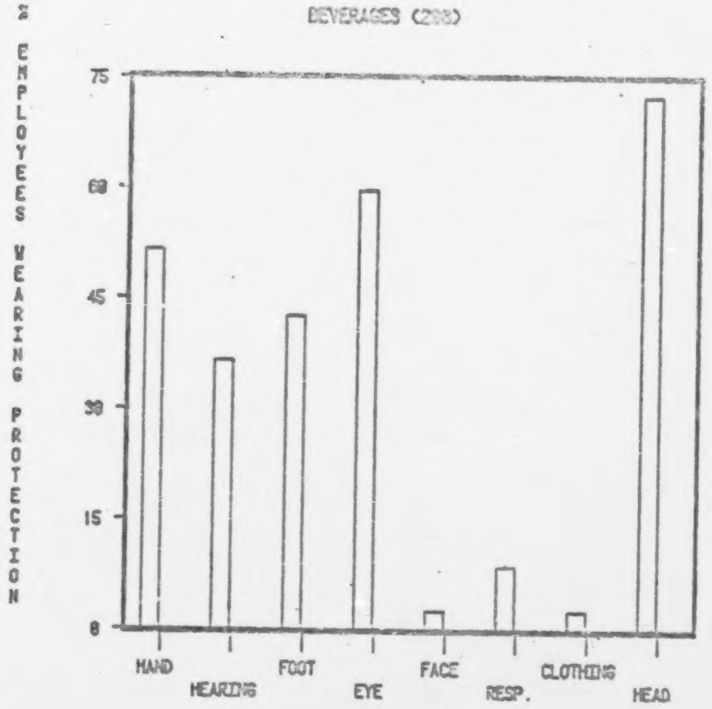
PRESERVED FRUITS & VEGETABLES (203)



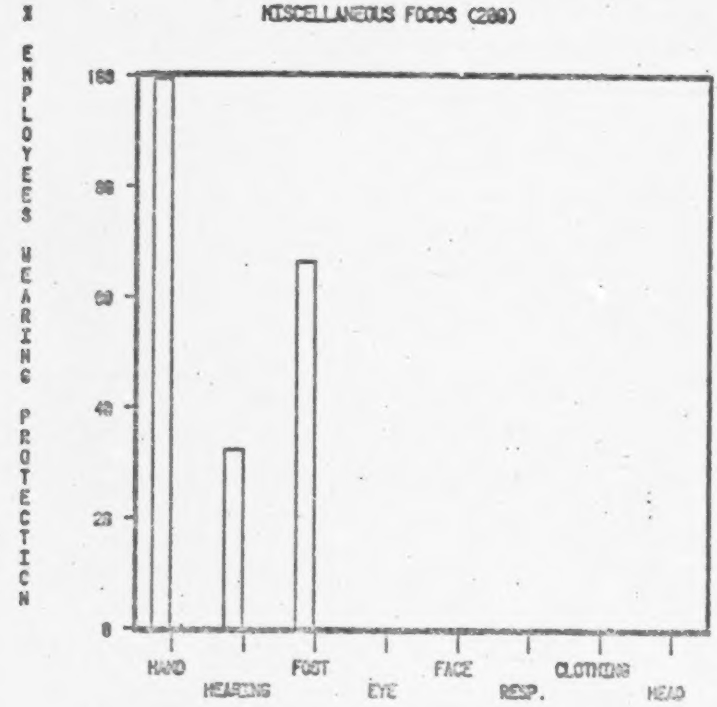
GRAIN MILL PRODUCTS (204)



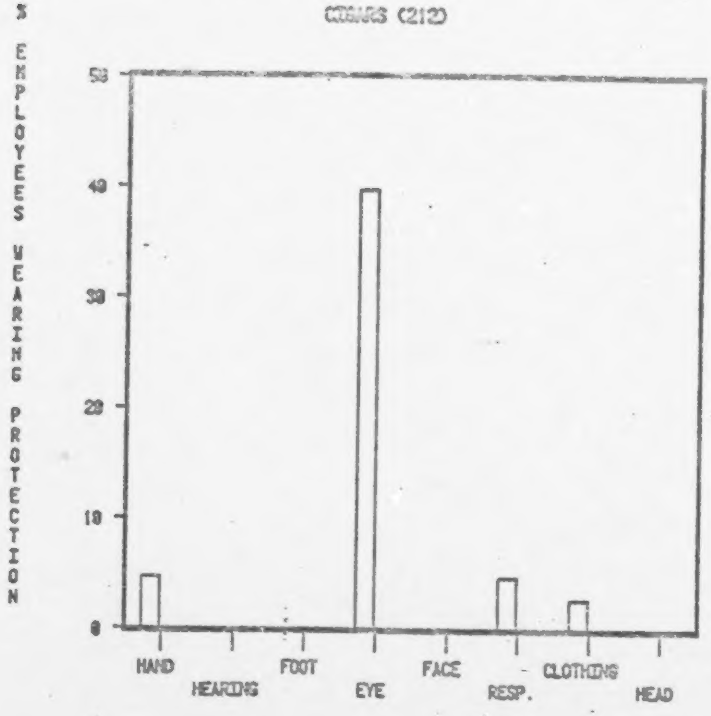
SUGAR & CONFECTIONARY PRODUCTS (206)



BEVERAGES (208)

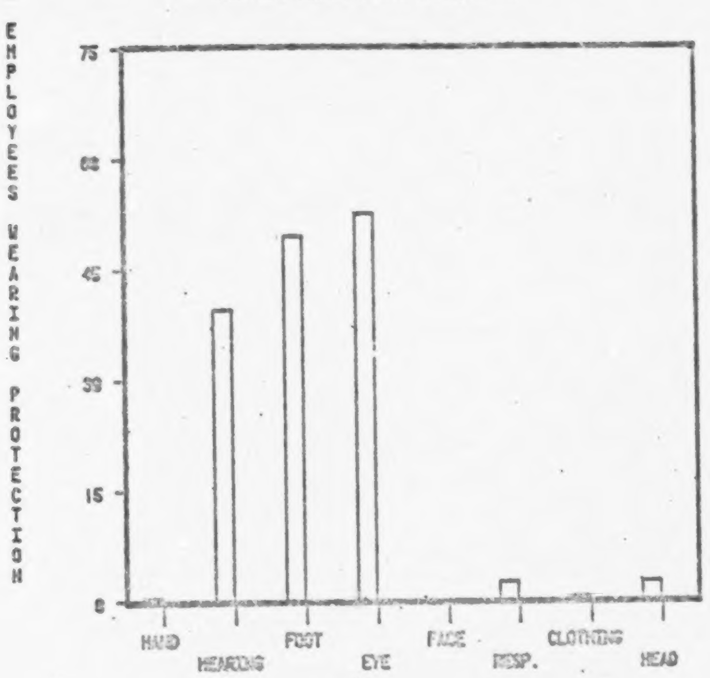


MISCELLANEOUS FOODS (209)

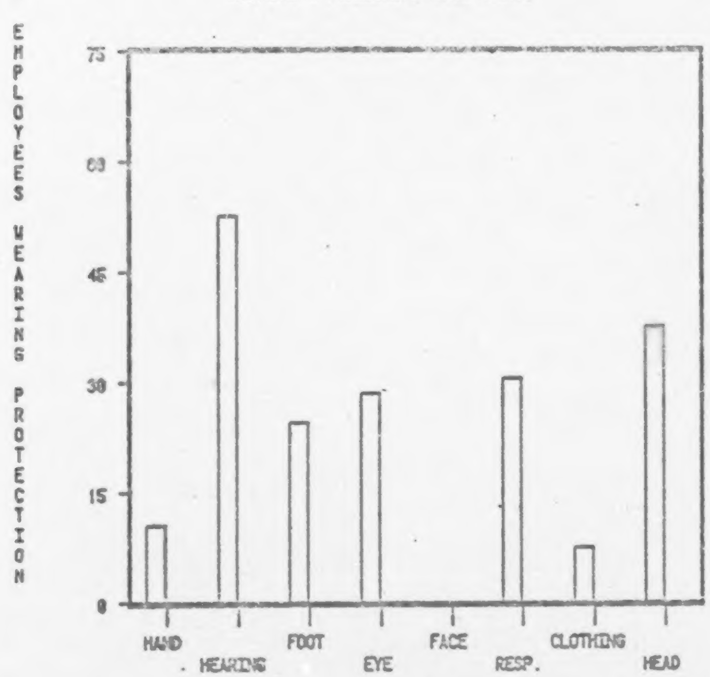


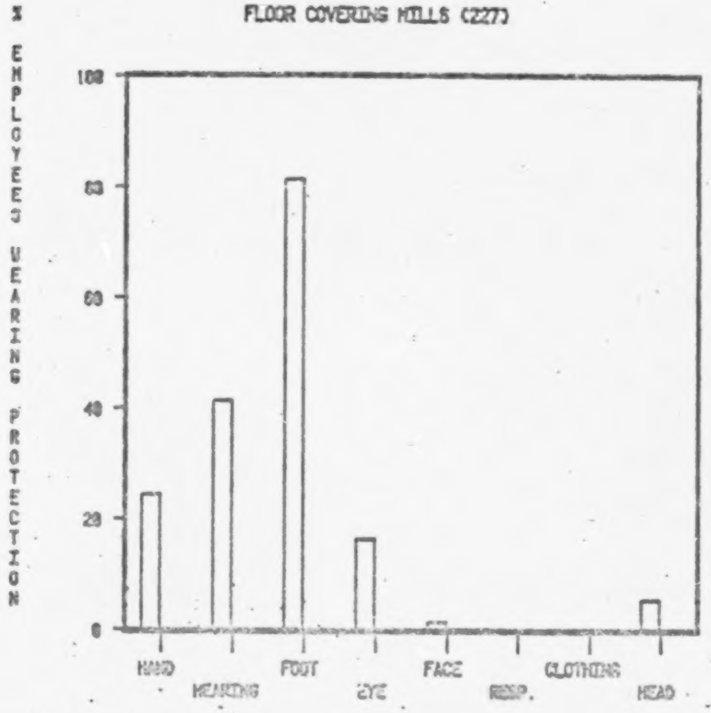
CIGARS (212)

WEAVING MILLS SYNTHETICS (222)

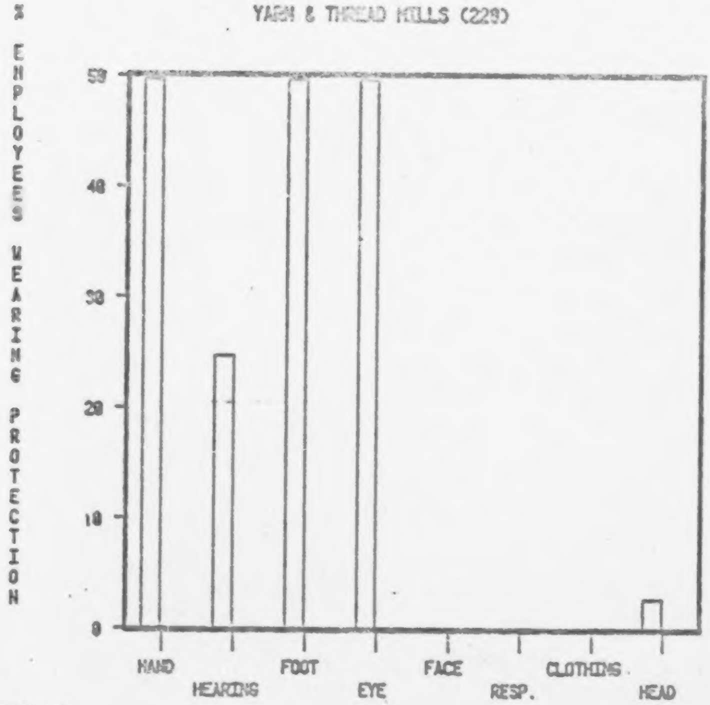


WEAVING & FINISHING WOOL (223)

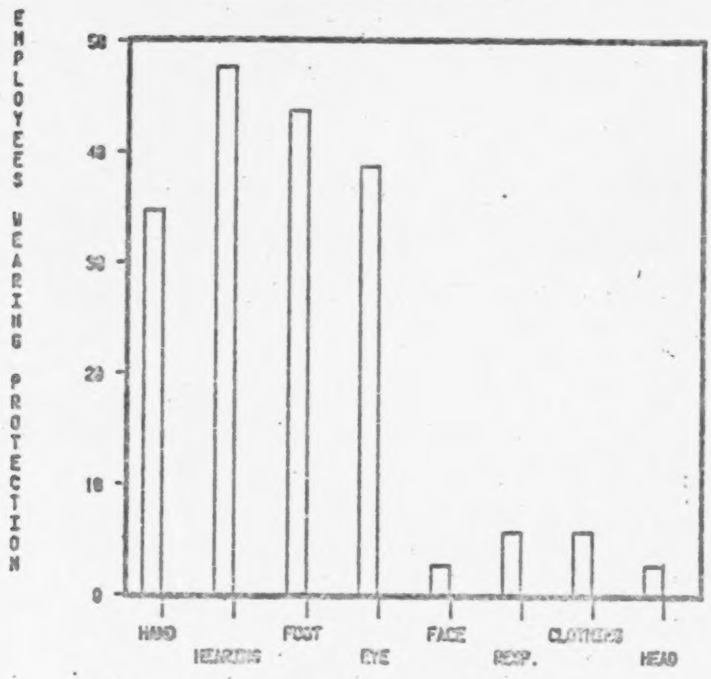


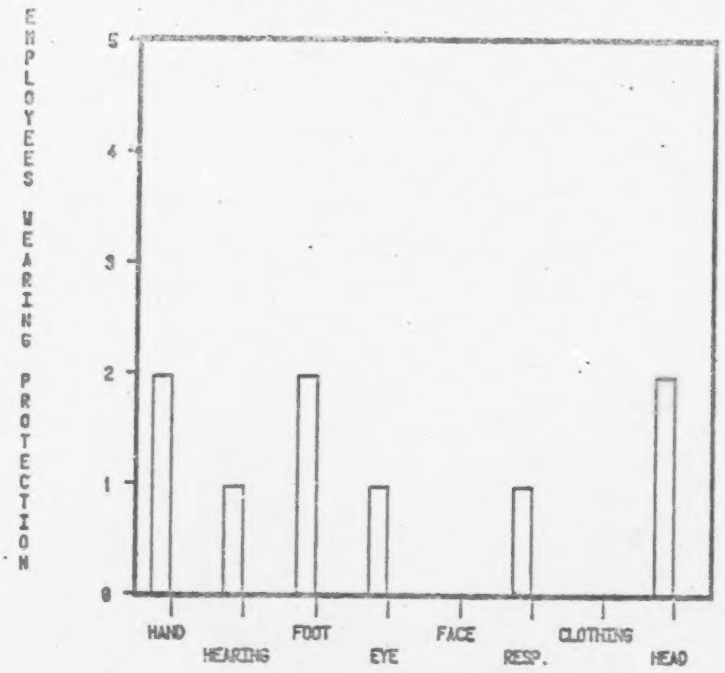


FLOOR COVERING MILLS (227)

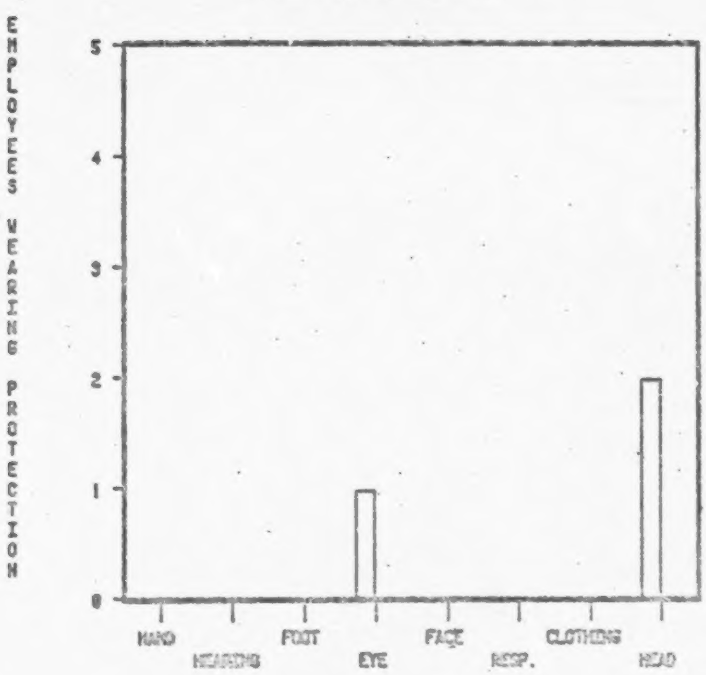


YARN & THREAD MILLS (229)

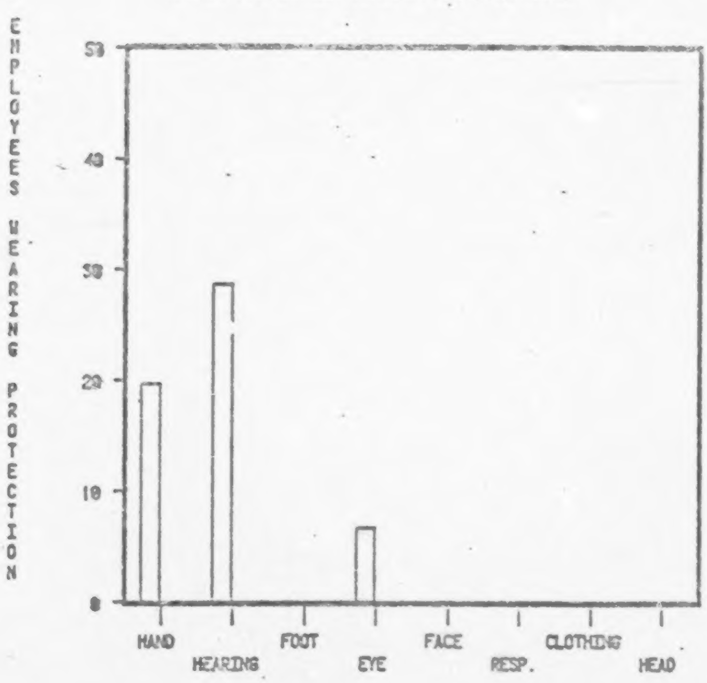

MISCELLANEOUS TEXTILE PRODUCTS (229)

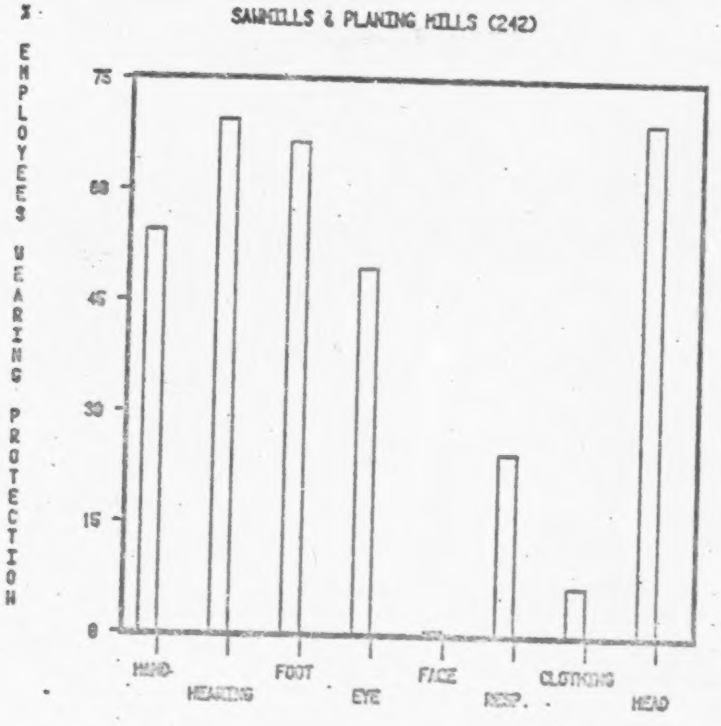

MEN'S & BOY'S SUITS & COATS (231)

MISCELLANEOUS APPAREL (238)

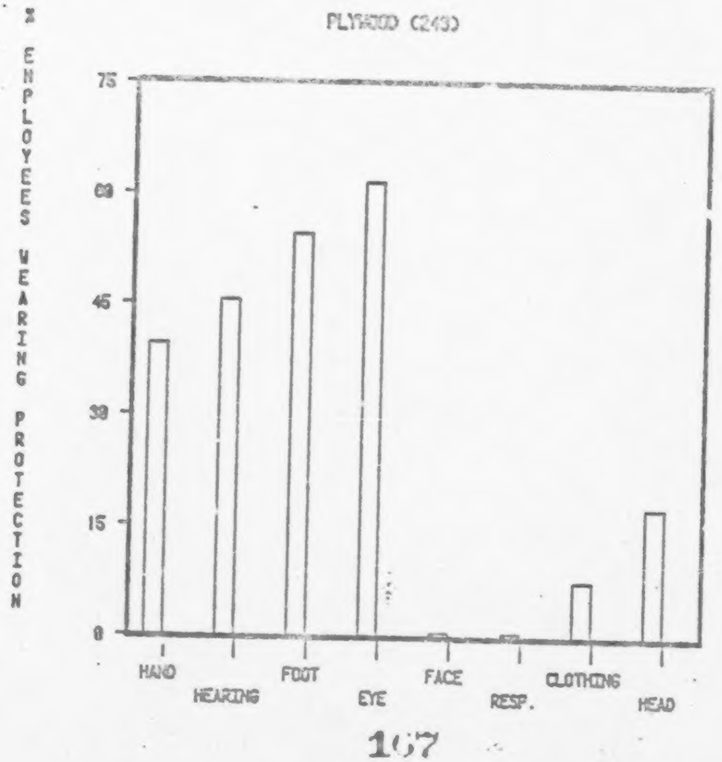


MISC. FABRICATED TEXTILE PRODUCTS (239)

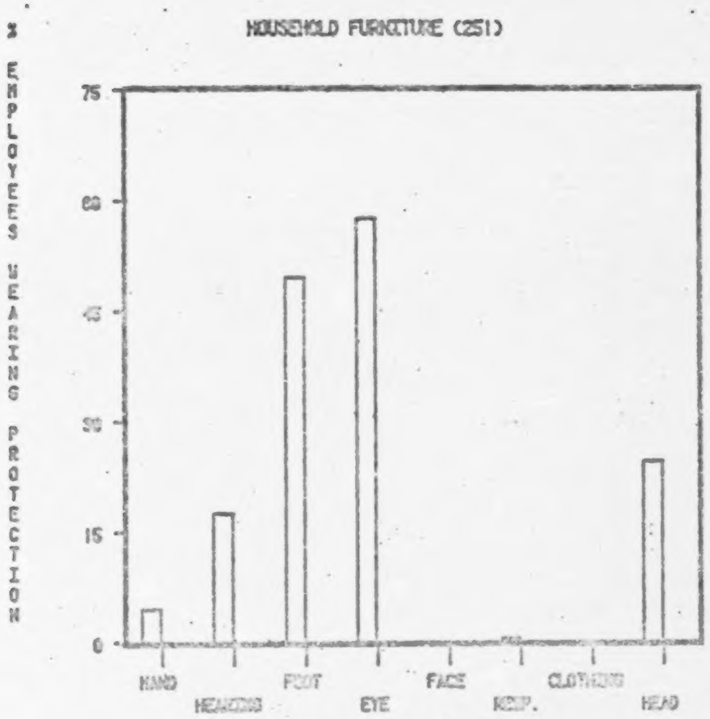




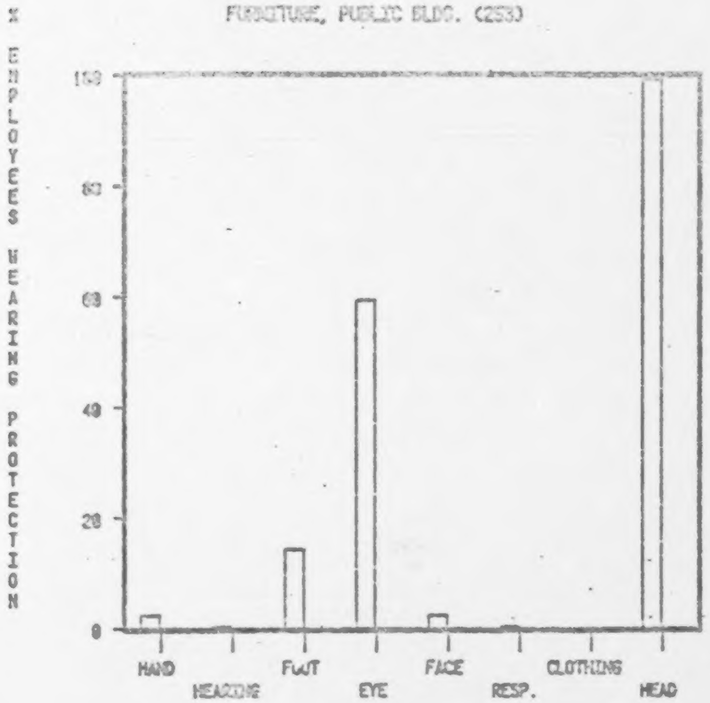
SAWMILLS & PLANING MILLS (242)



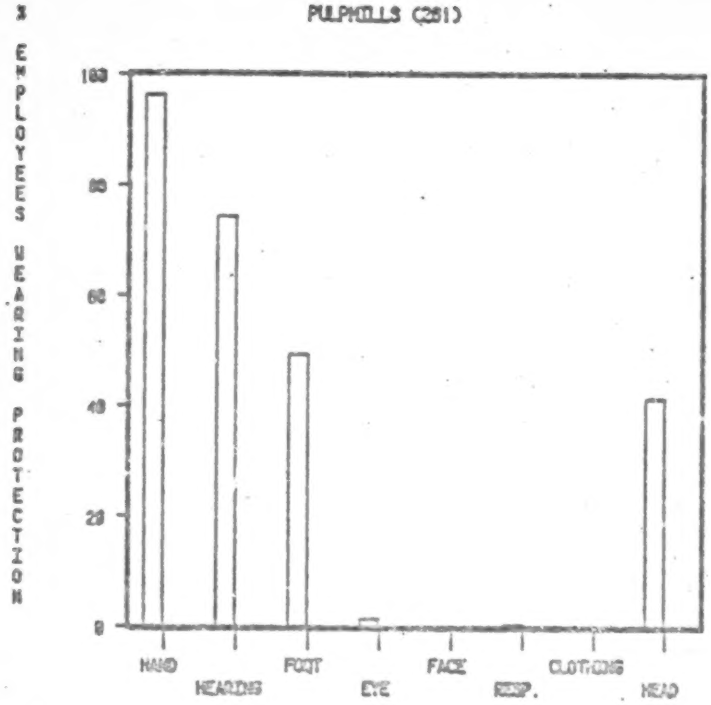
PLYWOOD (243)

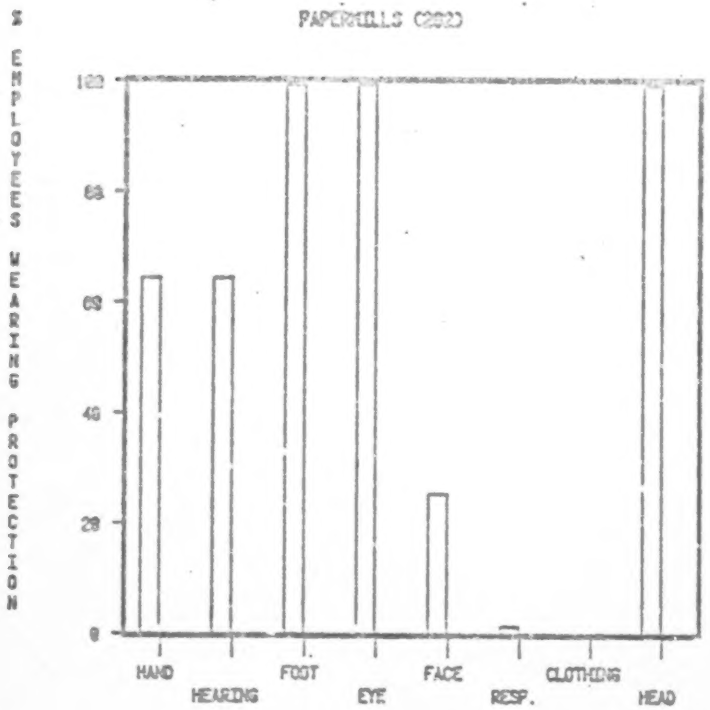


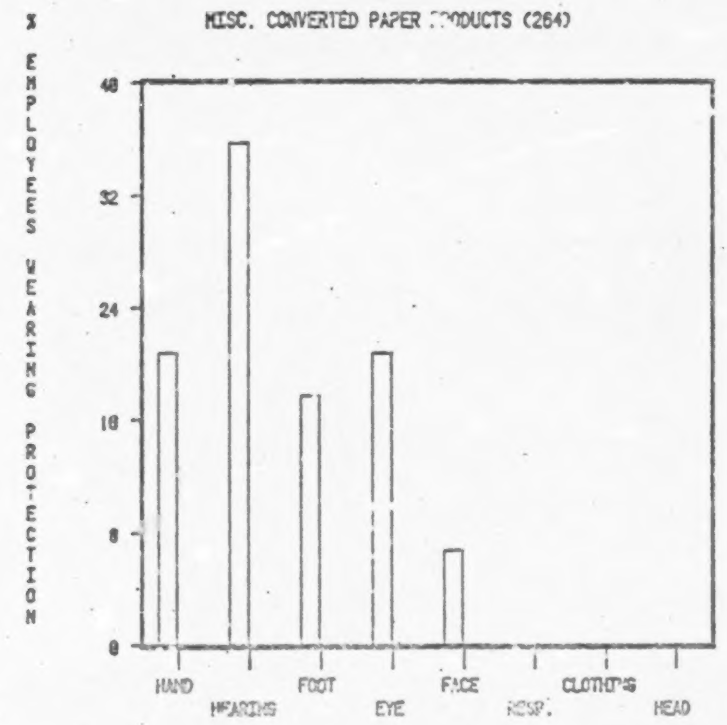
HOUSEHOLD FURNITURE (251)

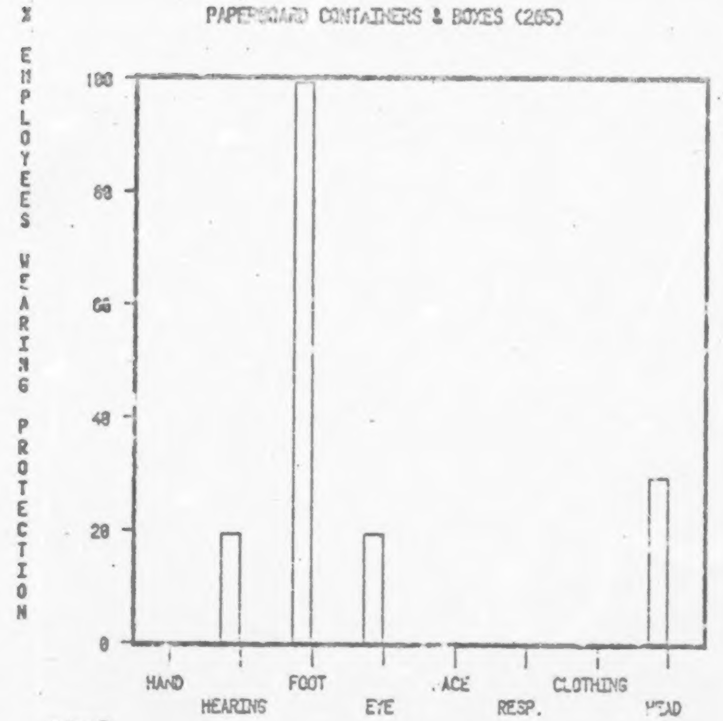


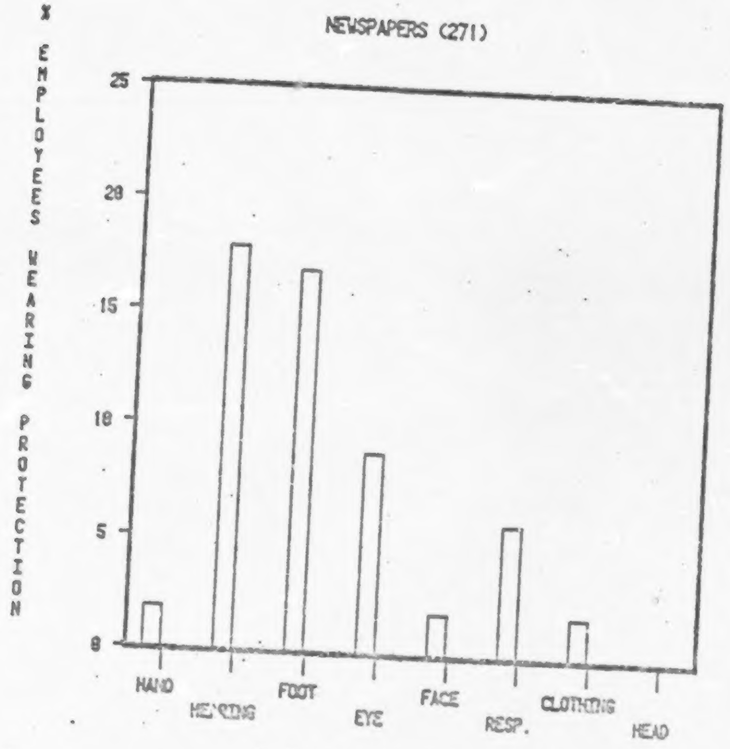
FURNITURE, PUBLIC BLDG. (253)

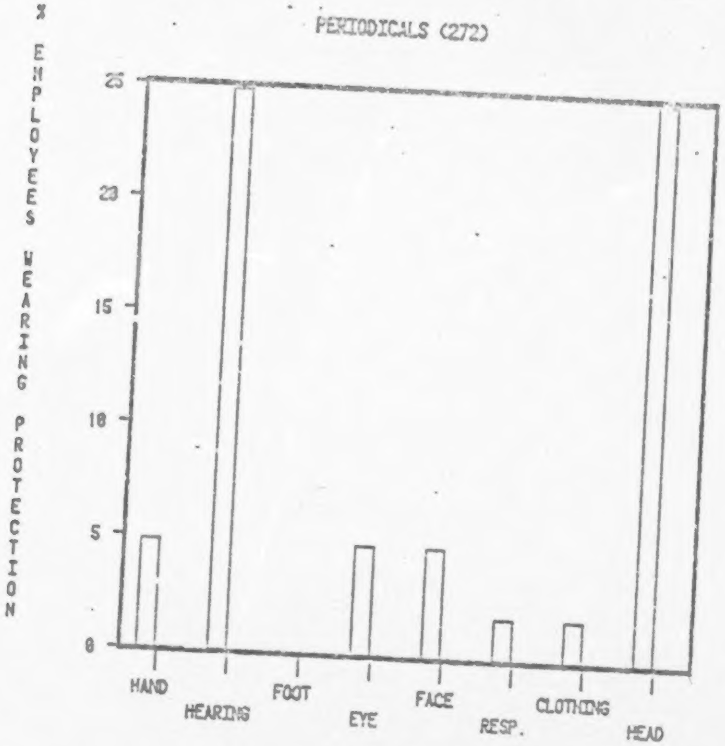

PULPMILLS (261)
% EMPLOYEES WEARING PROTECTION
100
80
60
40
20
0
HAND
HEARING
FOOT
EYE
FACE
RESP.
CLOTHING
HEAD

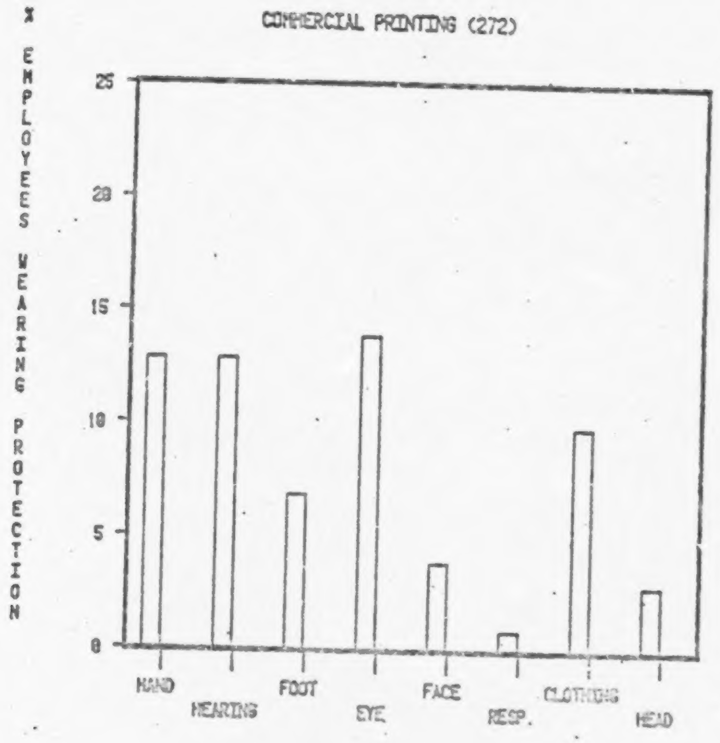

PAPERMILLS (262)
% EMPLOYEES WEARING PROTECTION
100
80
60
40
20
0
HAND
HEARING
FOOT
EYE
FACE
RESP.
CLOTHING
HEAD

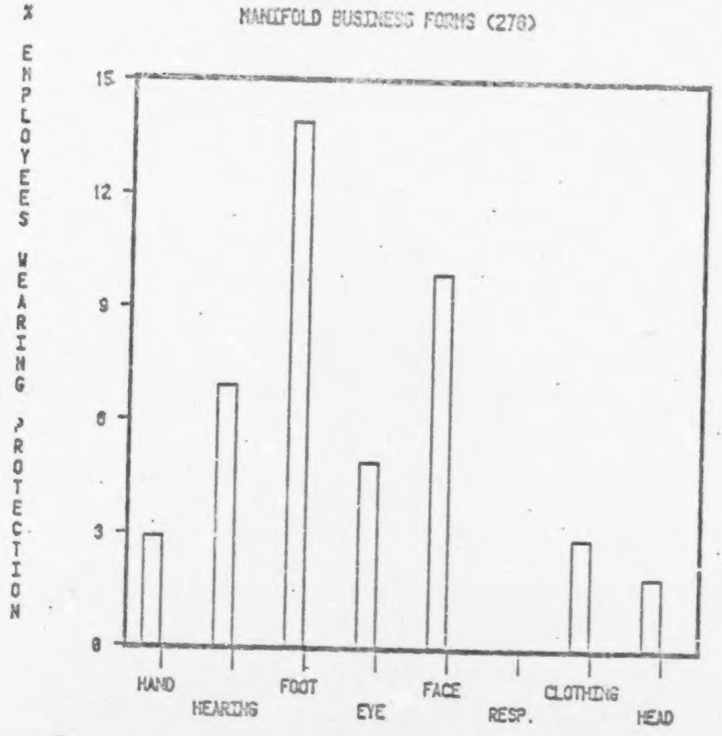

MISC. CONVERTED PAPER PRODUCTS (264)
% EMPLOYEES WEARING PROTECTION
40
32
24
16
8
0
HAND
HEARING
FOOT
EYE
FACE
RESP.
CLOTHING
HEAD

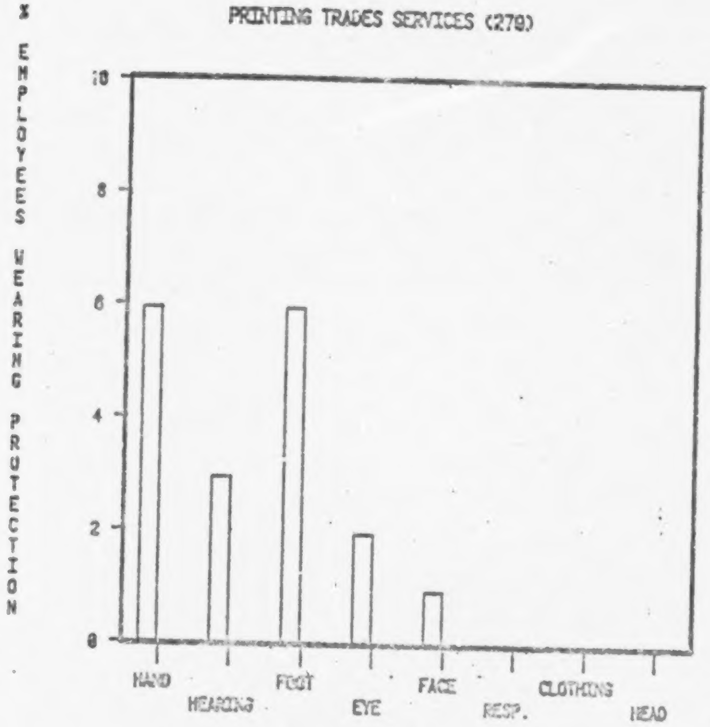

PAPERBOARD CONTAINERS & BOXES (265)
% EMPLOYEES WEARING PROTECTION
100
80
60
40
20
0
HAND
HEARING
FOOT
EYE
FACE
RESP.
CLOTHING
HEAD

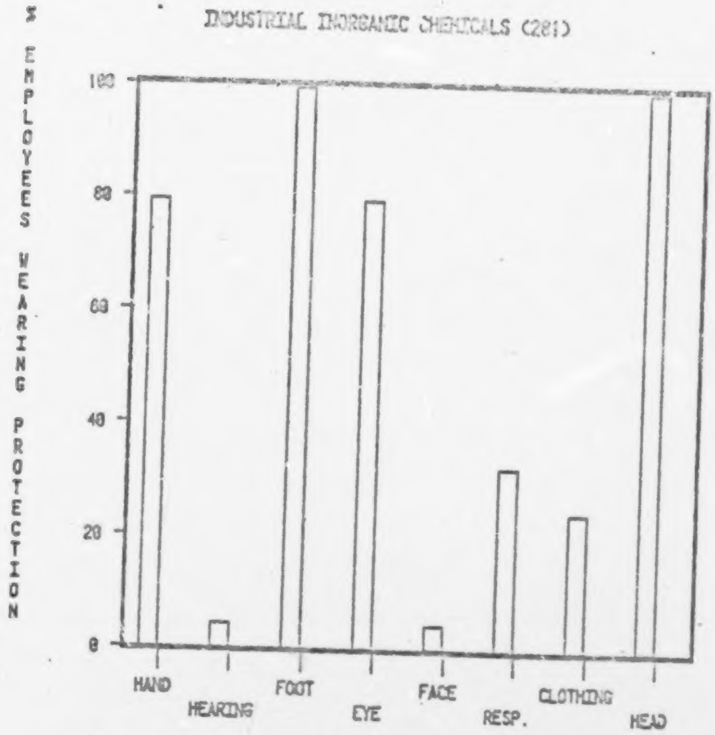

NEWSPAPERS (271)


PERIODICALS (272)

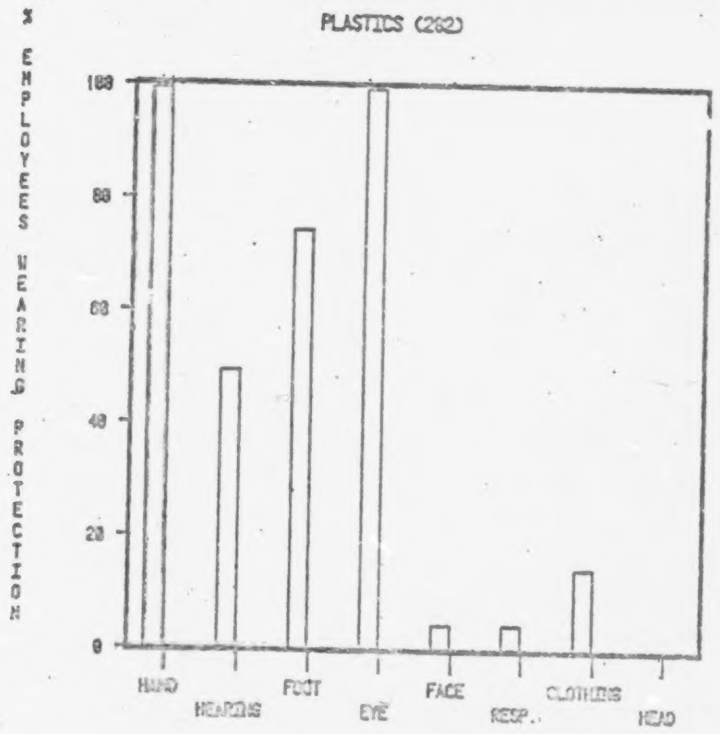

COMMERCIAL PRINTING (272)


MANIFOLD BUSINESS FORMS (276)

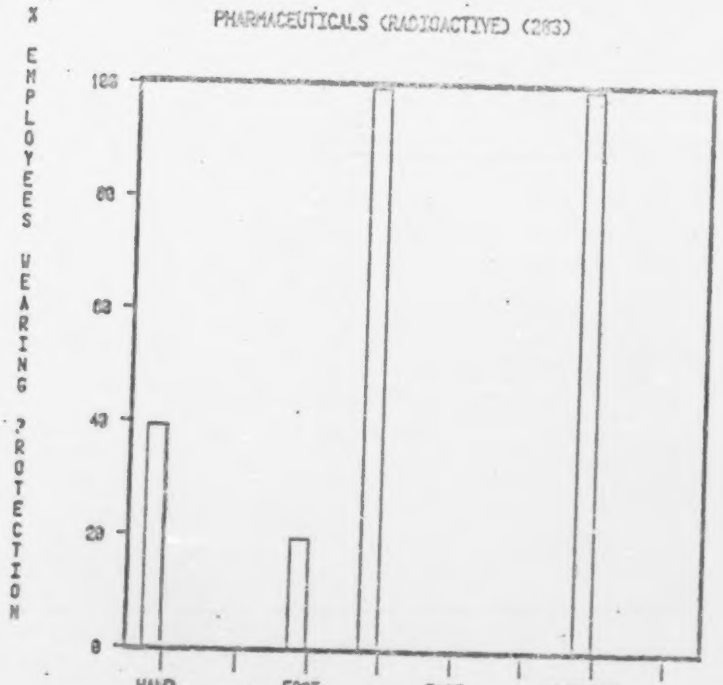

PRINTING TRADES SERVICES (279)
% EMPLOYEES WEARING PROTECTION
10
8
6
4
2
0
HAND
HEARING
FOOT
EYE
FACE
RESP.
CLOTHING
HEAD


INDUSTRIAL INORGANIC CHEMICALS (281)
% EMPLOYEES WEARING PROTECTION
100
80
60
40
20
0
HAND
HEARING
FOOT
EYE
FACE
RESP.
CLOTHING
HEAD

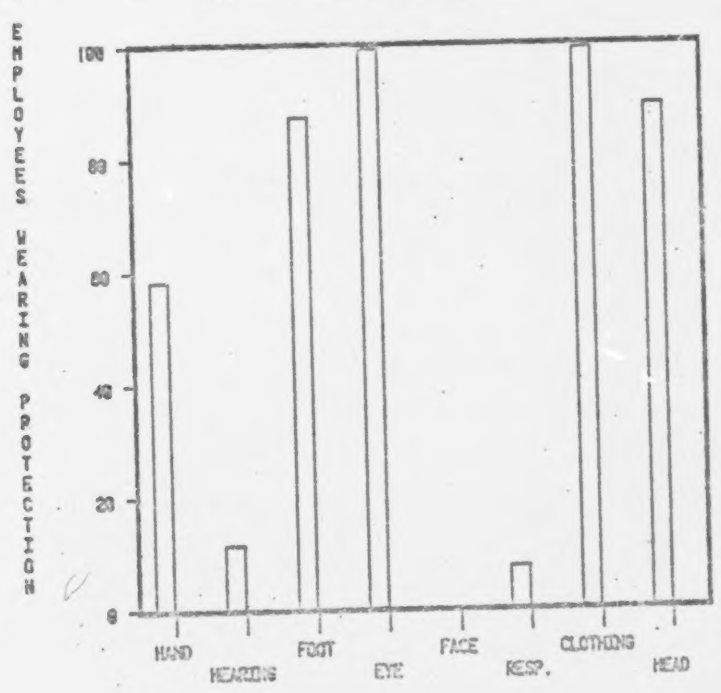
PLASTICS (282)



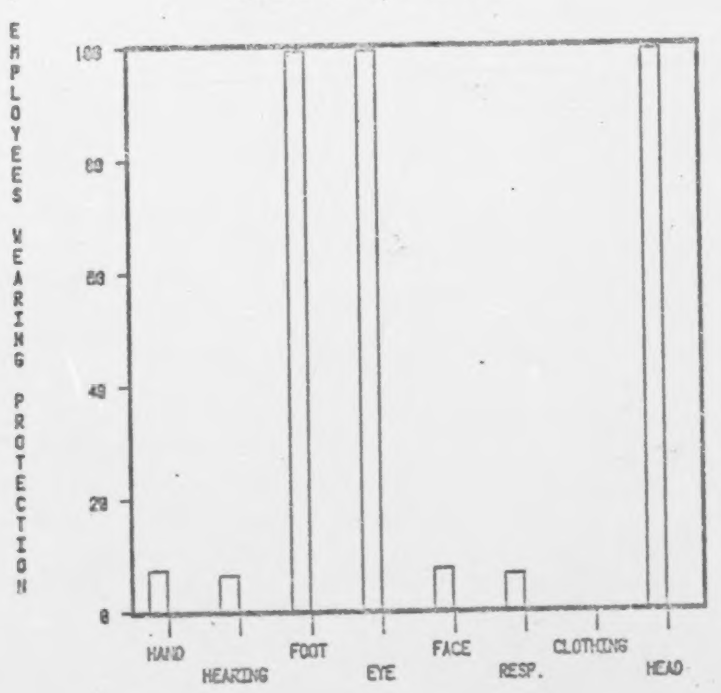
PHARMACEUTICALS (RADIOACTIVE) (283)

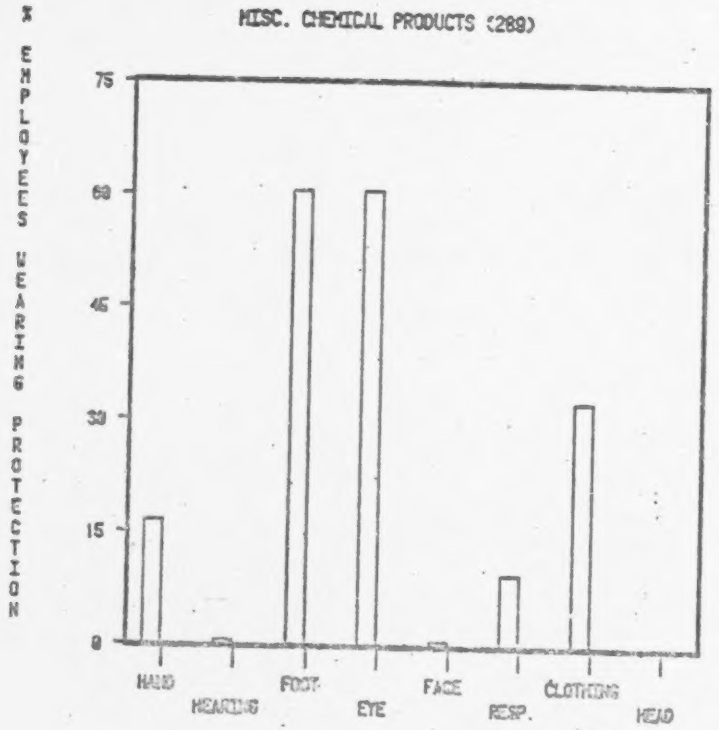


INDUSTRIAL ORGANIC CHEMICALS (286)

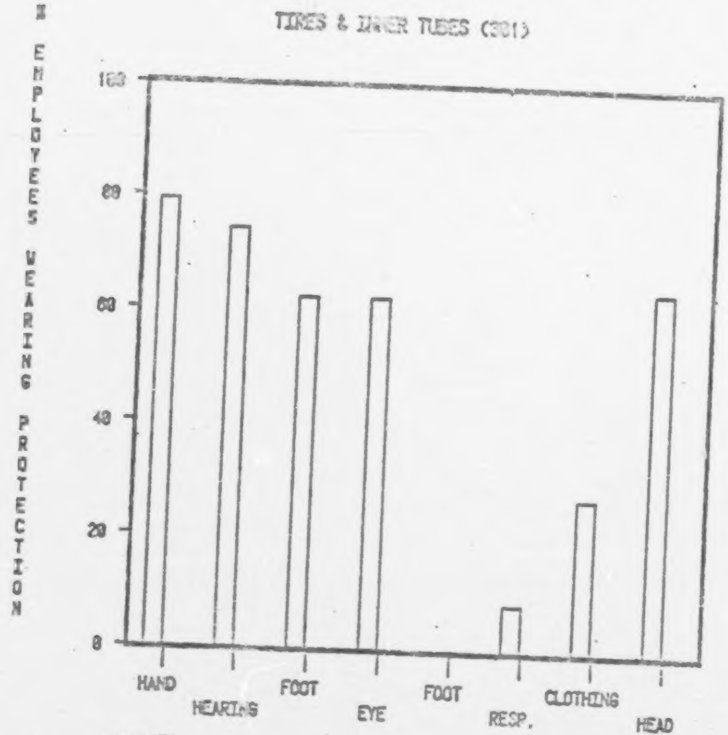


AGRICULTURE CHEMICALS (287)

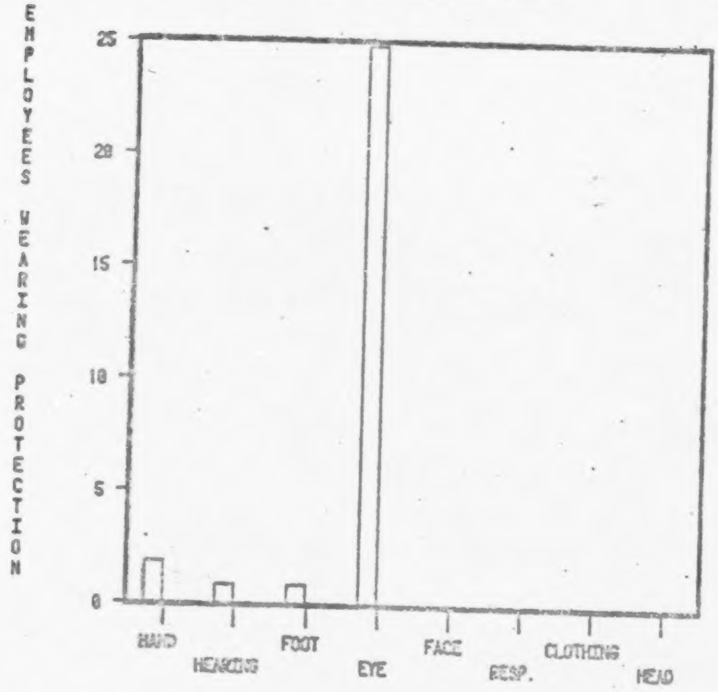


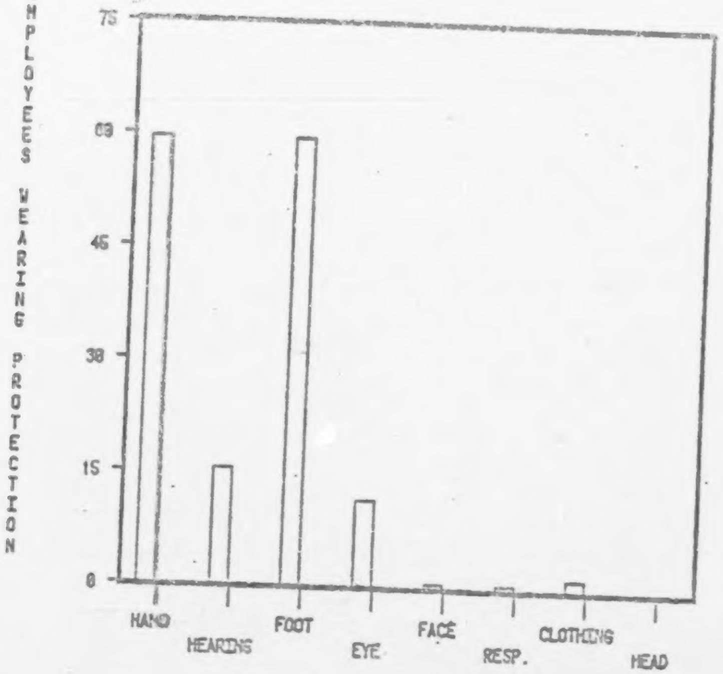


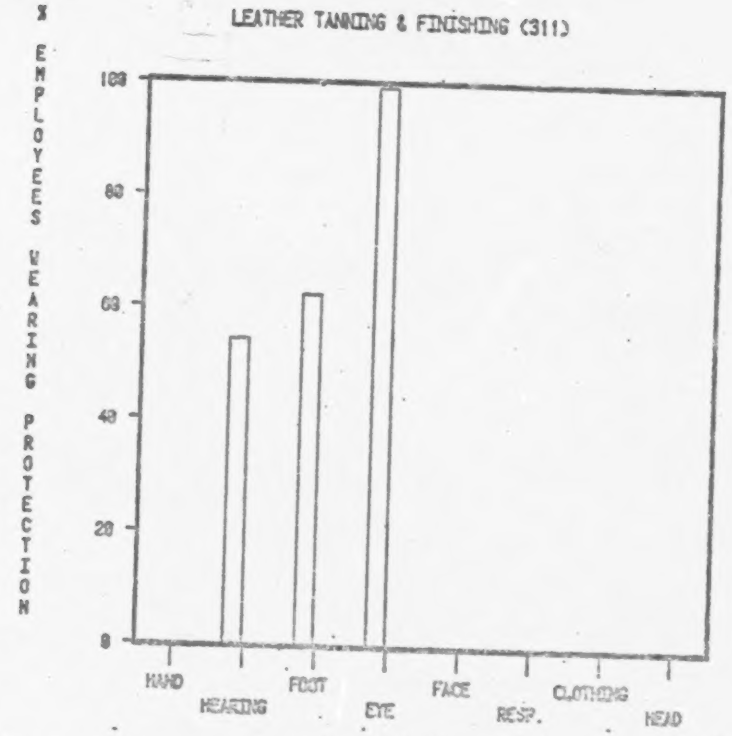
MISC. CHEMICAL PRODUCTS (289)



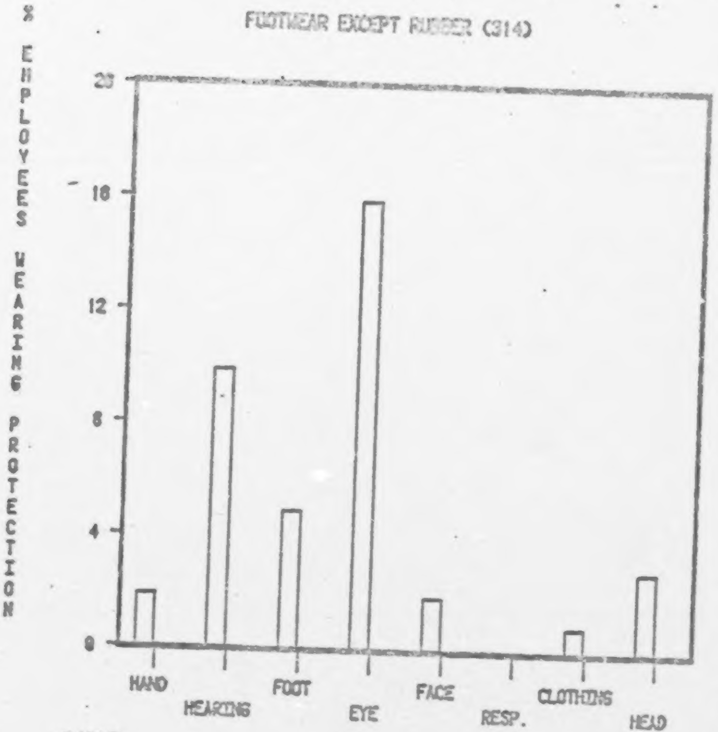
TIRES & INNER TUBES (301)


RUBBER PLASTICS FOOTWEAR (302)

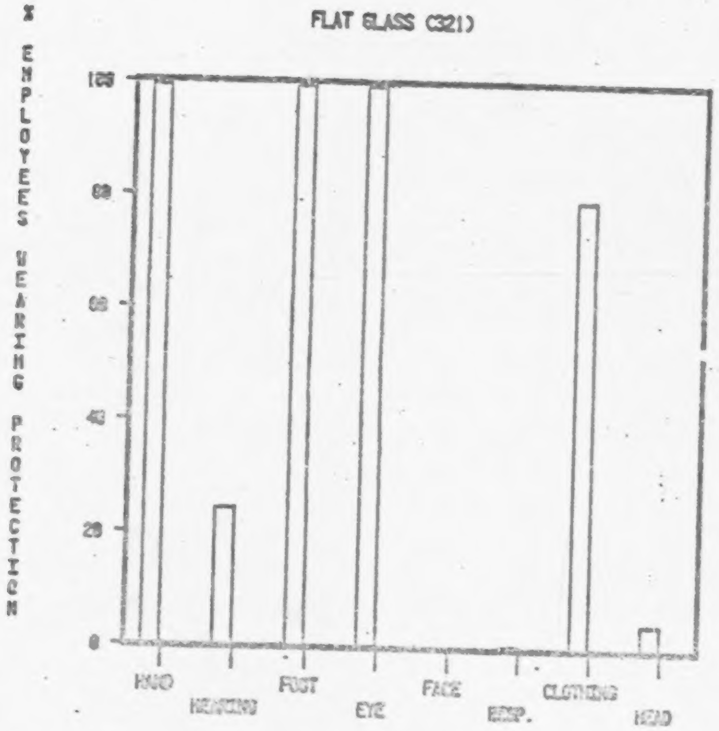

MISC. PLASTIC PRODUCTS (307)

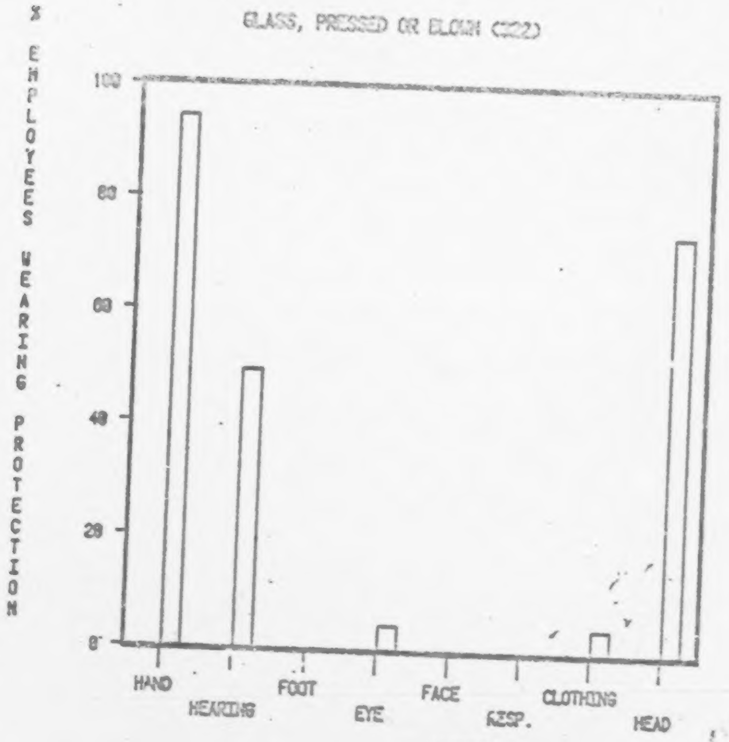


LEATHER TANNING & FINISHING (311)

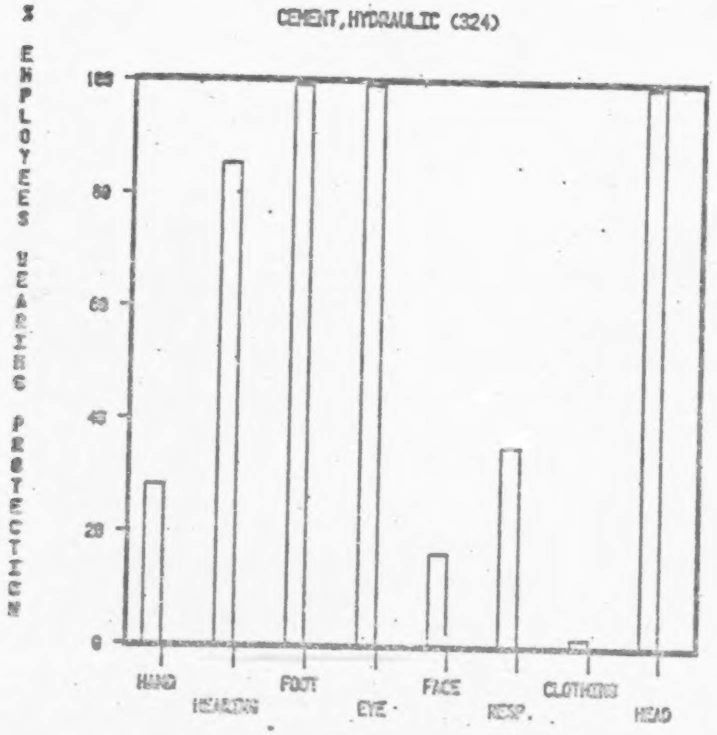


FOOTWEAR EXCEPT RUBBER (314)

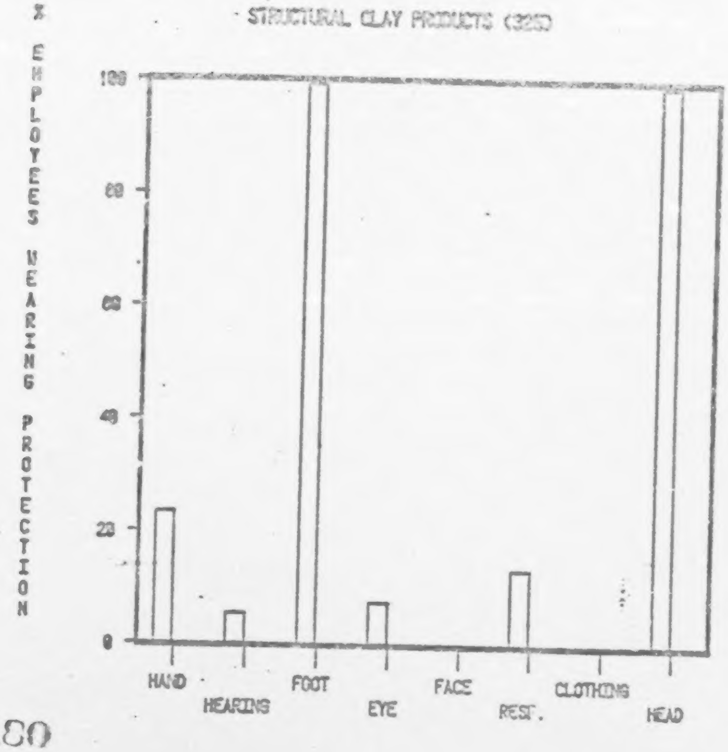

FLAT GLASS (321)
% EMPLOYEES WEARING PROTECTION
100
80
60
40
20
0
HAND
HEARING
FOOT
EYE
FACE
RESP.
CLOTHING
HEAD


GLASS, PRESSED OR BLOWN (322)
% EMPLOYEES WEARING PROTECTION
100
80
60
40
20
0
HAND
HEARING
FOOT
EYE
FACE
RESP.
CLOTHING
HEAD

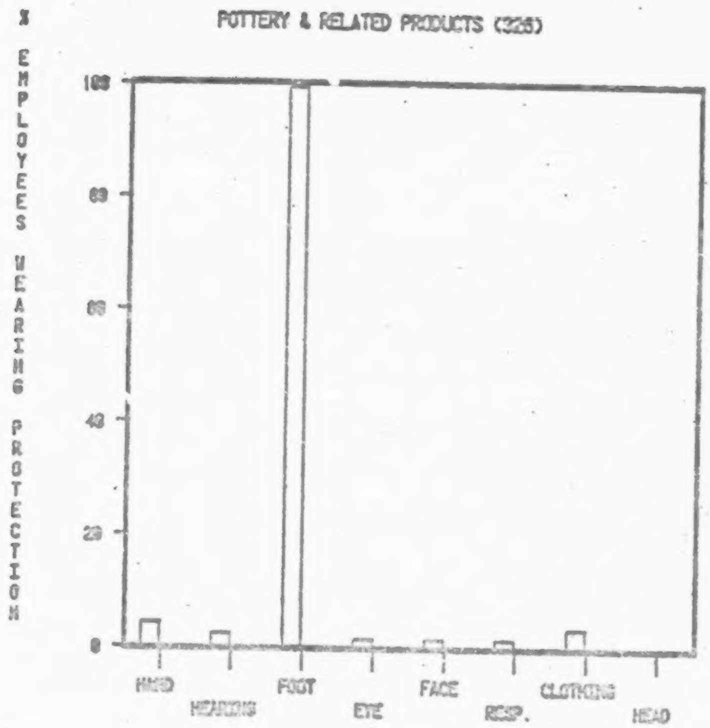
CEMENT, HYDRAULIC (324)



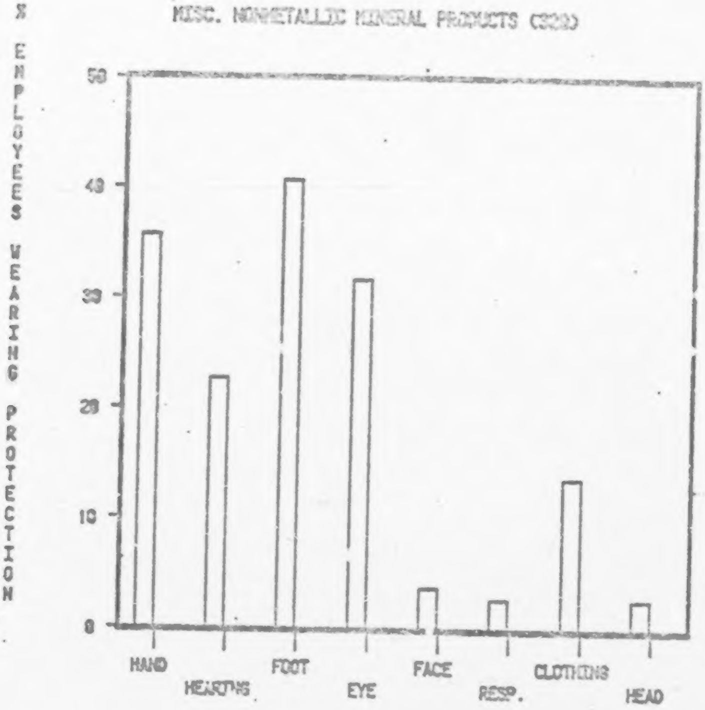
STRUCTURAL CLAY PRODUCTS (325)



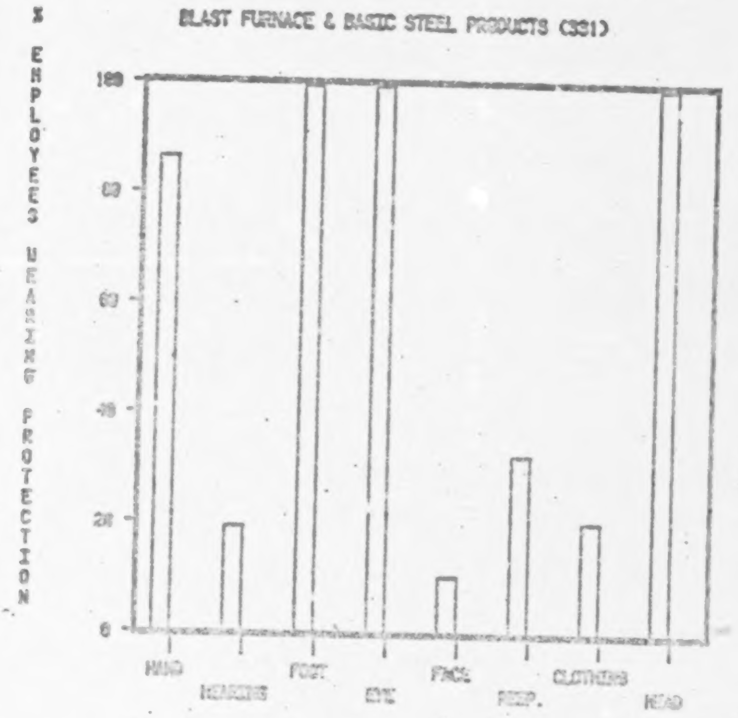
POTTERY & RELATED PRODUCTS (326)



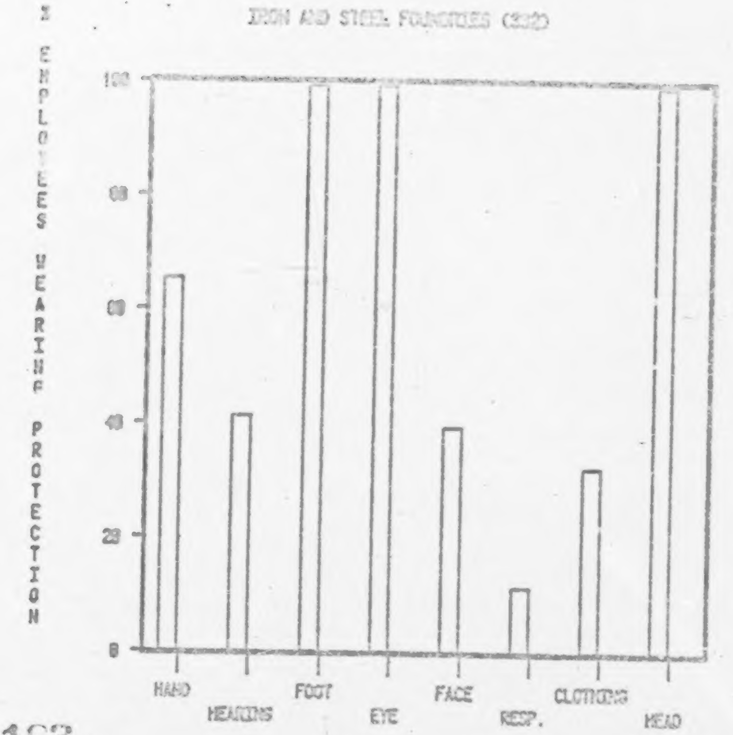
MISC. NONMETALLIC MINERAL PRODUCTS (329)



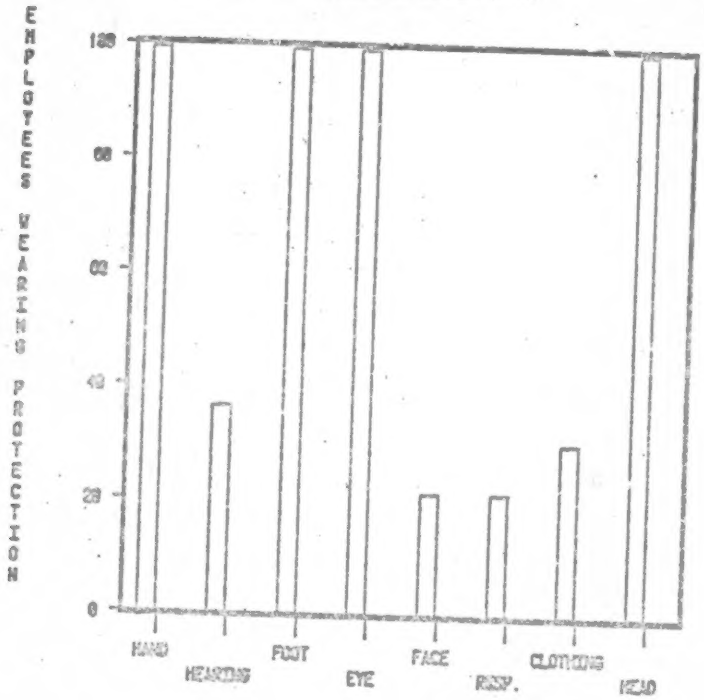
BLAST FURNACE & BASIC STEEL PRODUCTS (331)



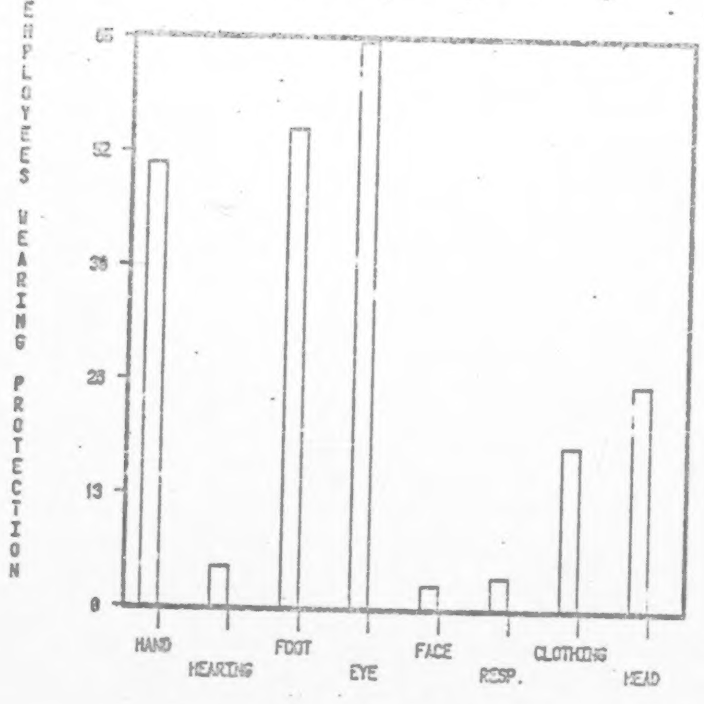
IRON AND STEEL FOUNDRIES (332)



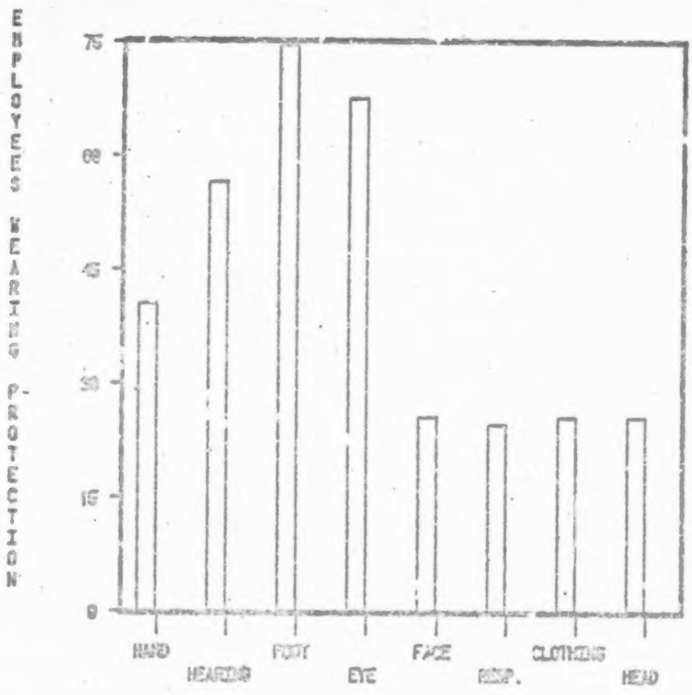
PRIMARY NONFERROUS METALS (333)



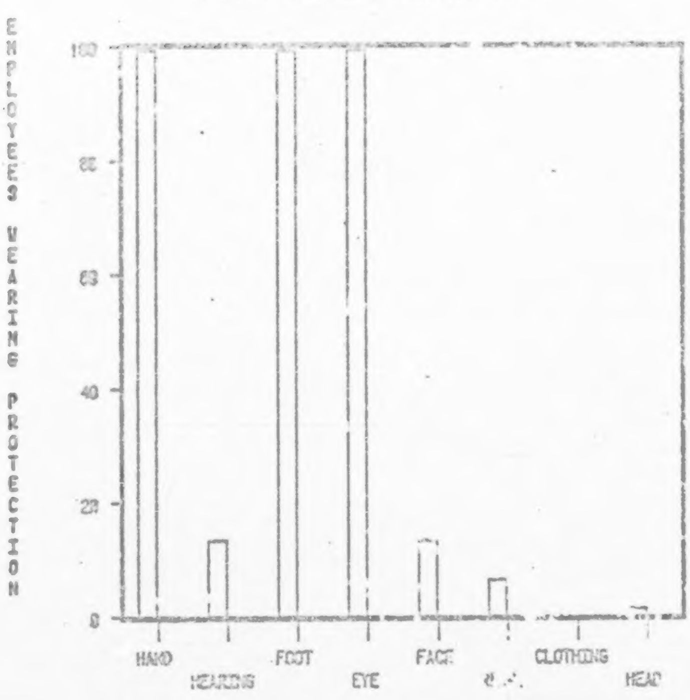
NONFERROUS ROLLING & DRAWING (335)



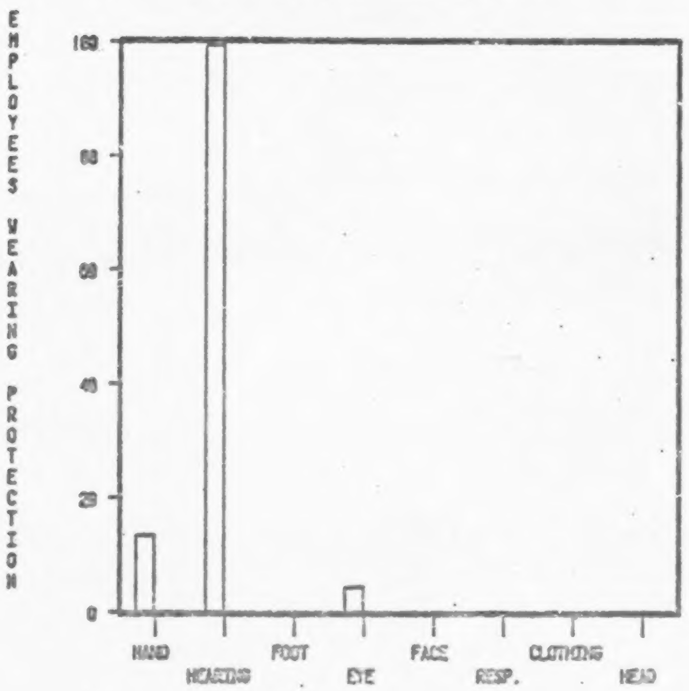
NONFERROUS FOUNDRIES (336)



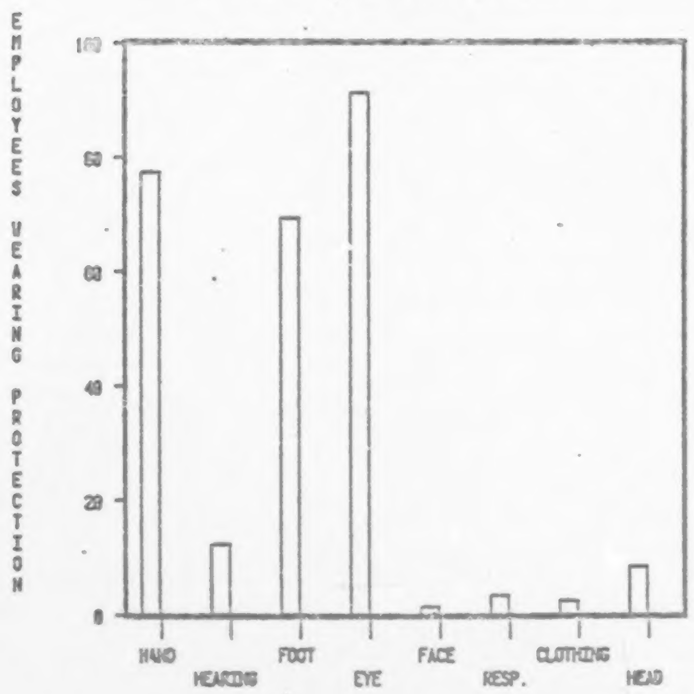
MISC. PRIMARY METAL PRODUCTS (339)



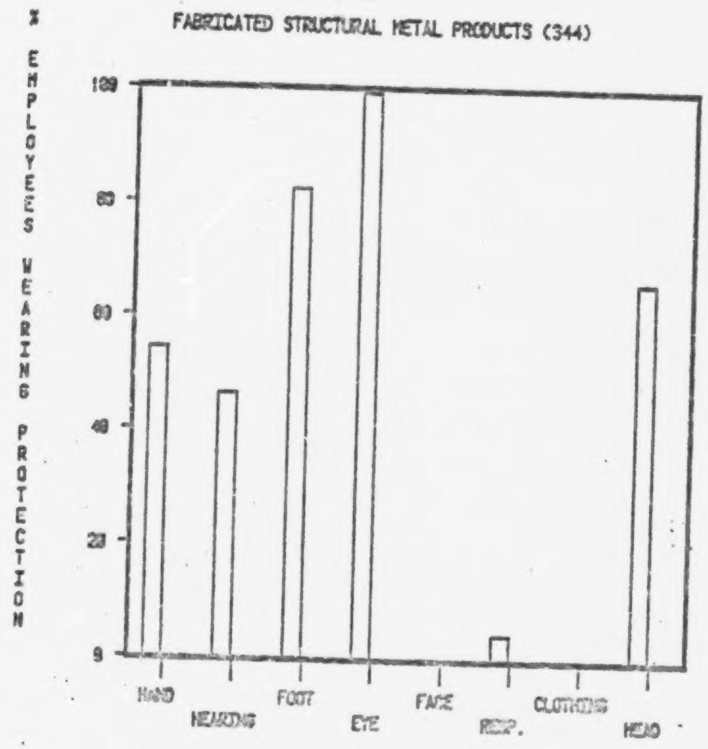
METAL CANS, SHIPPING CONTAINERS (341)



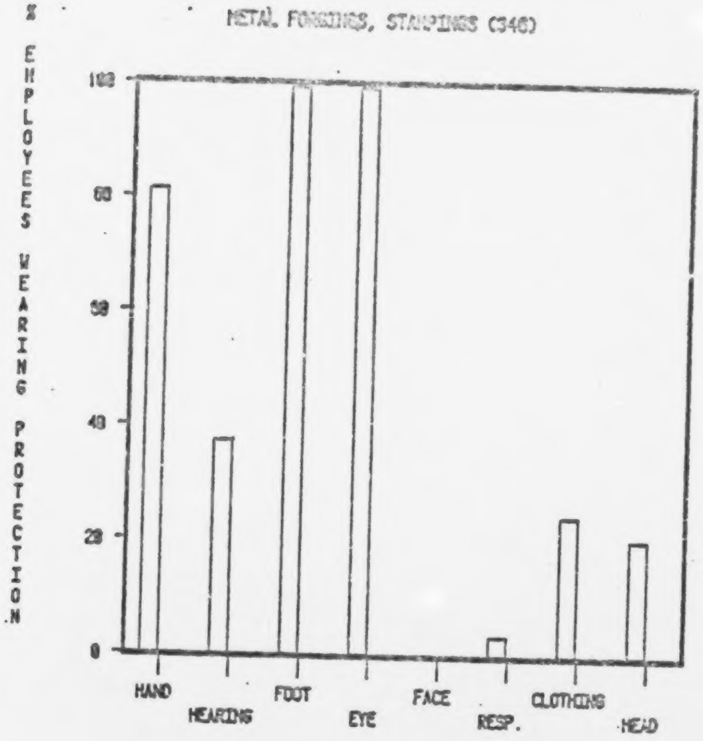
CUTLERY, HANDTOOLS, HARDWARE (342)



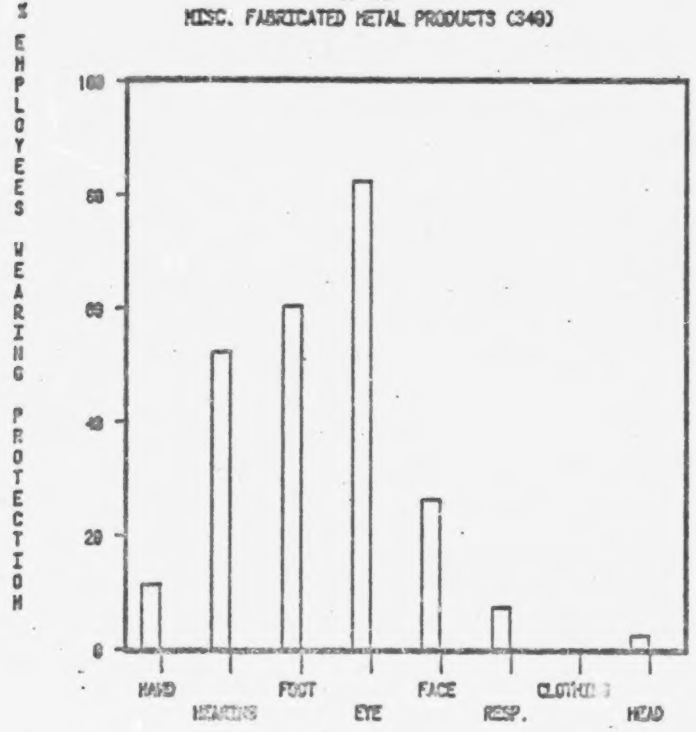
FABRICATED STRUCTURAL METAL PRODUCTS (344)

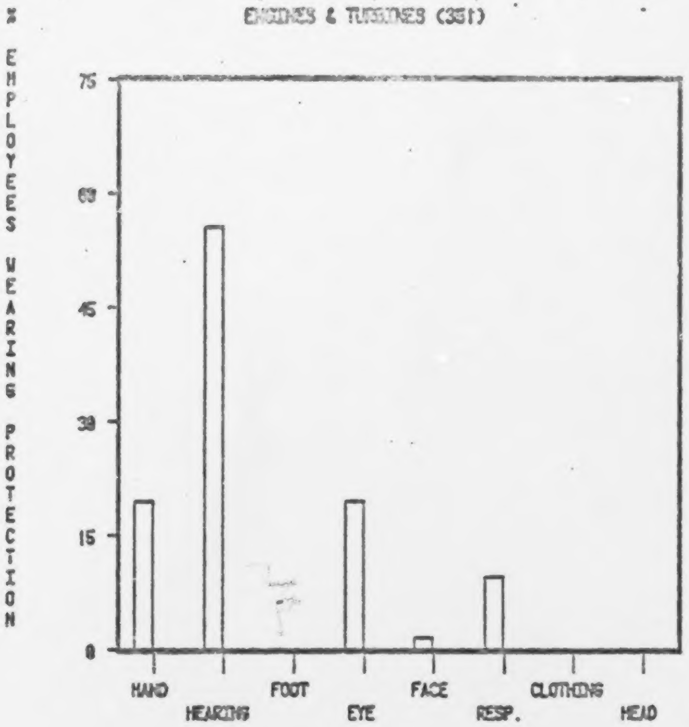


METAL FORGINGS, STAMPINGS (346)

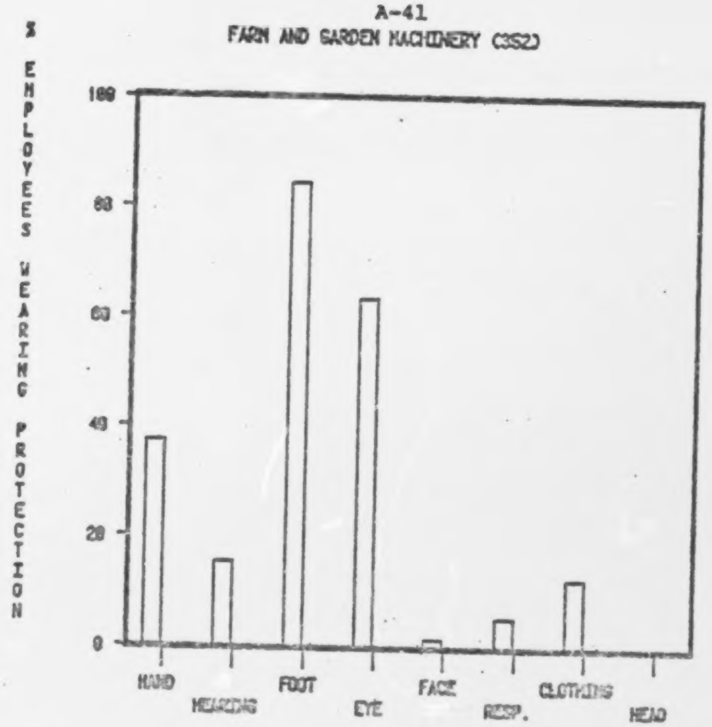


A-40

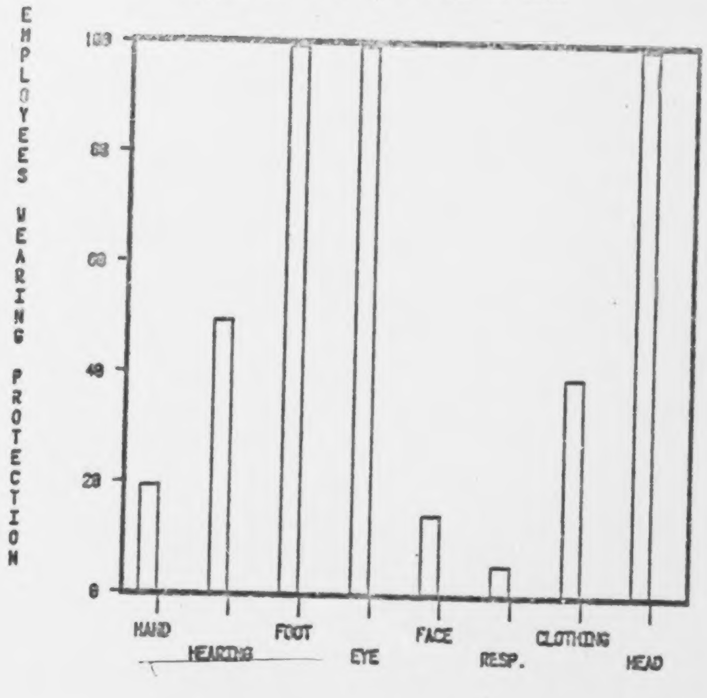

MISC. FABRICATED METAL PRODUCTS (349)
% EMPLOYEES WEARING PROTECTION
100
80
60
40
20
0
HAND
HEARING
FOOT
EYE
FACE
RESP.
CLOTHING
HEAD


ENGINES & TURBINES (351)
% EMPLOYEES WEARING PROTECTION
75
60
45
30
15
0
HAND
HEARING
FOOT
EYE
FACE
RESP.
CLOTHING
HEAD

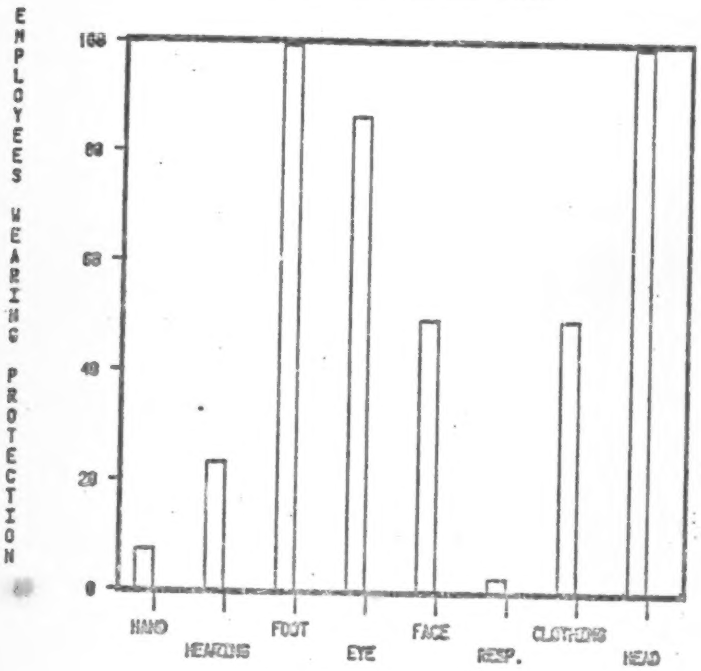
FARM AND GARDEN MACHINERY (352)



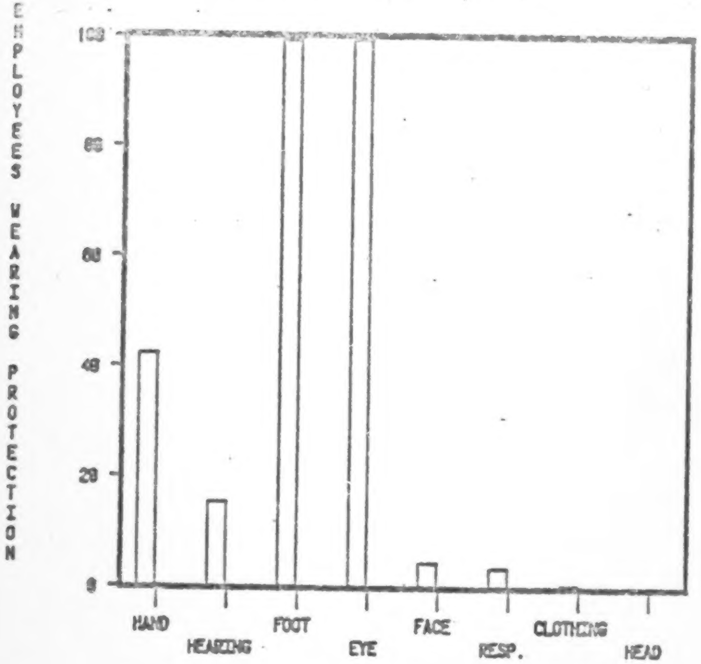
CONSTRUCTION & RELATED MACHINERY (353)



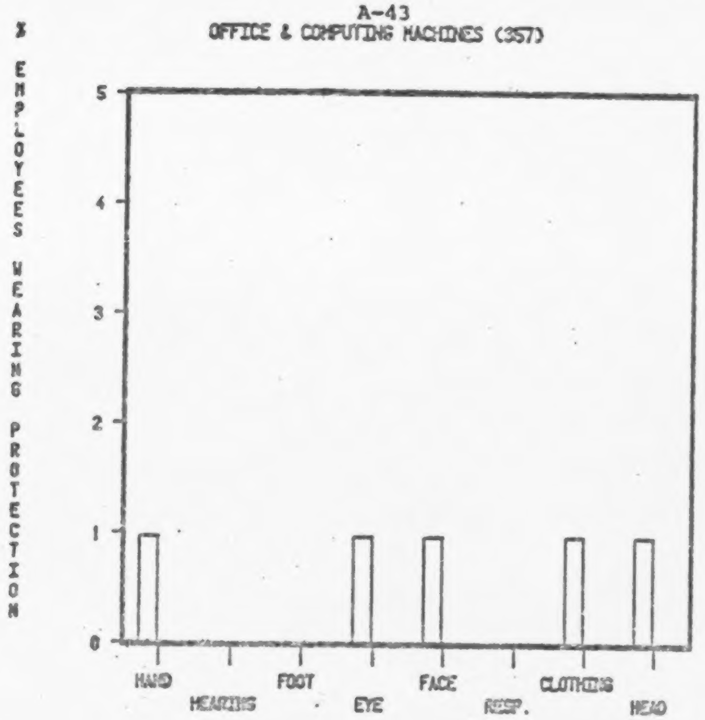
METALWORKING MACHINERY (354)



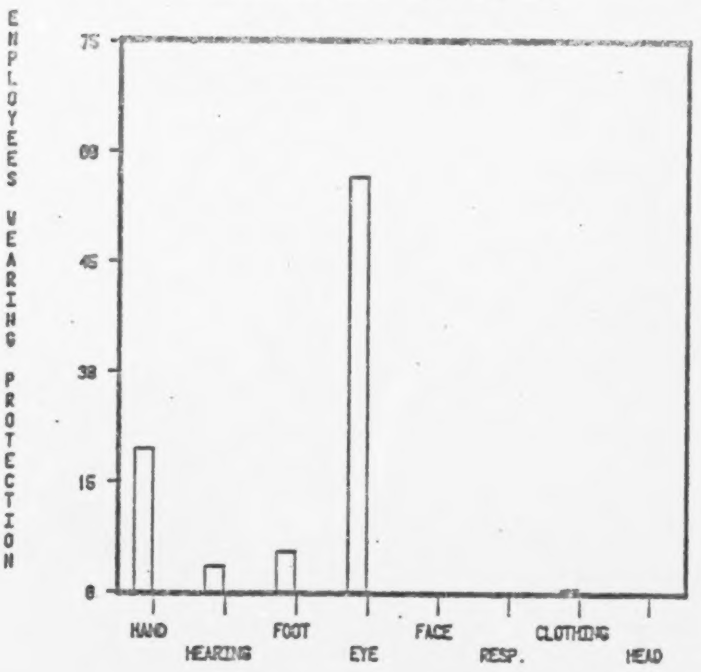
SPECIAL INDUSTRY MACHINERY (355)



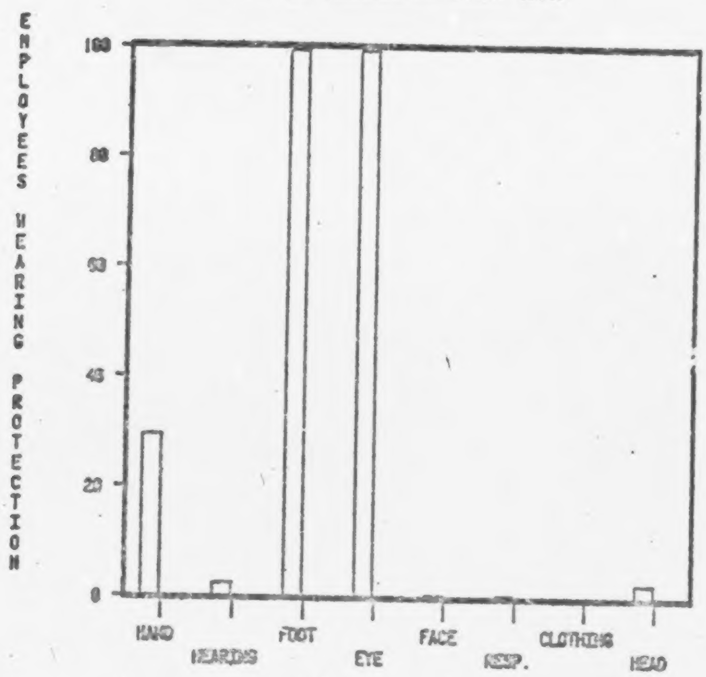
OFFICE & COMPUTING MACHINES (357)



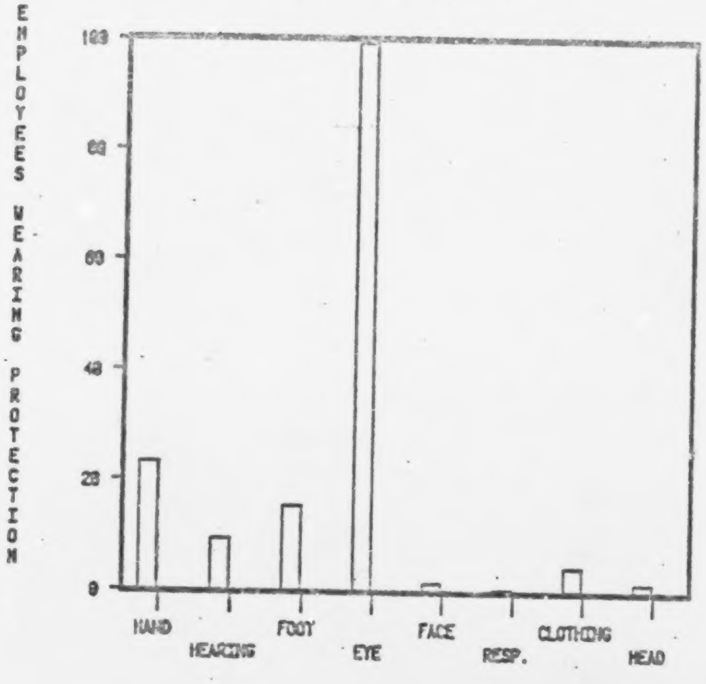
REFRIGERATION, SERVICE MACHINERY (358)



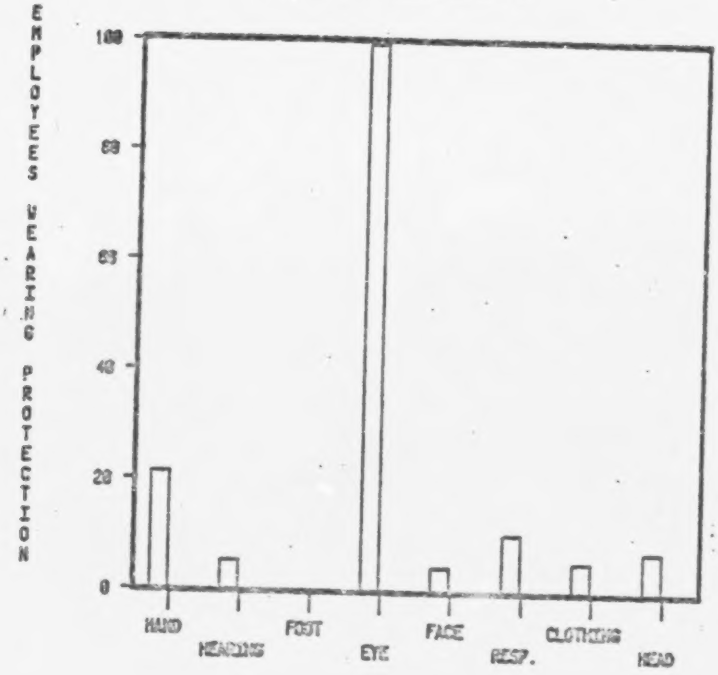
ELECTRIC DISTRIBUTING EQUIPMENT (361)



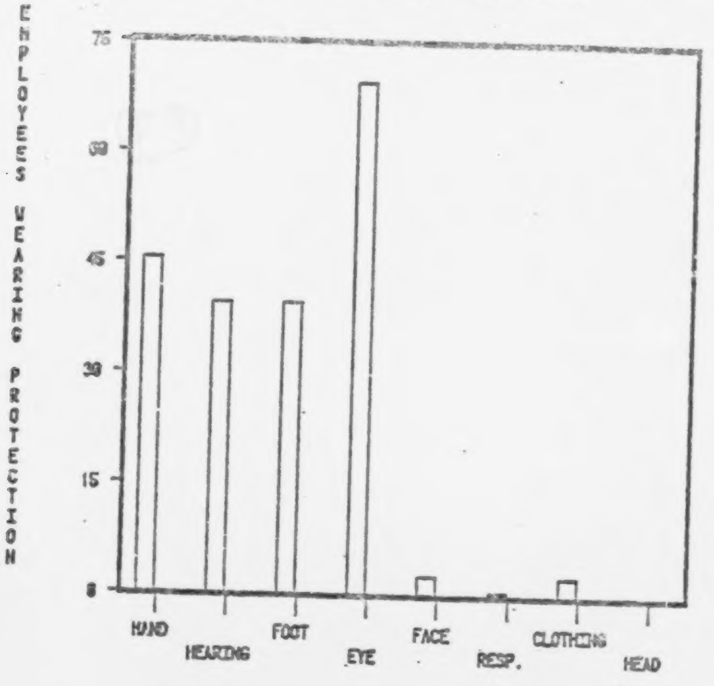
ELECTRICAL INDUSTRIAL APPARATUS (362)



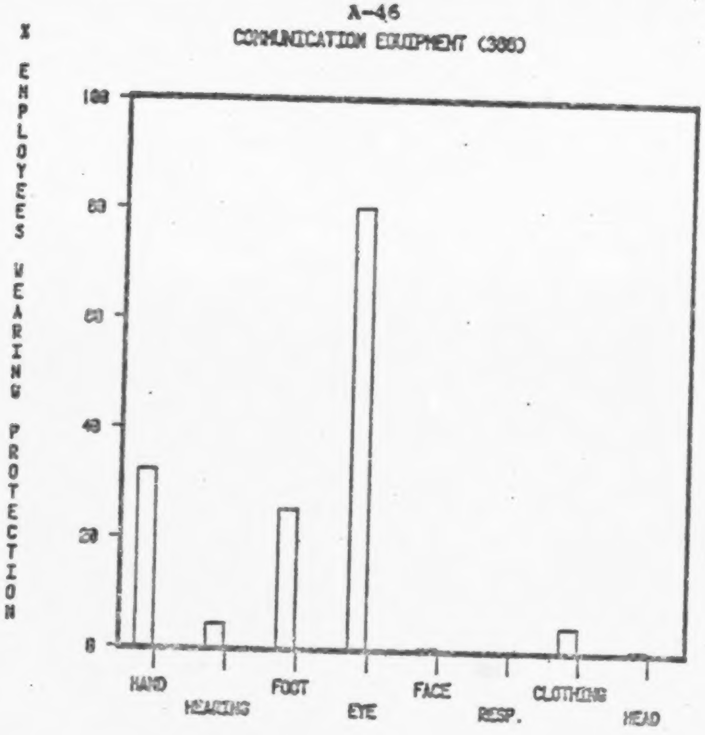
HOUSEHOLD APPLIANCES (363)



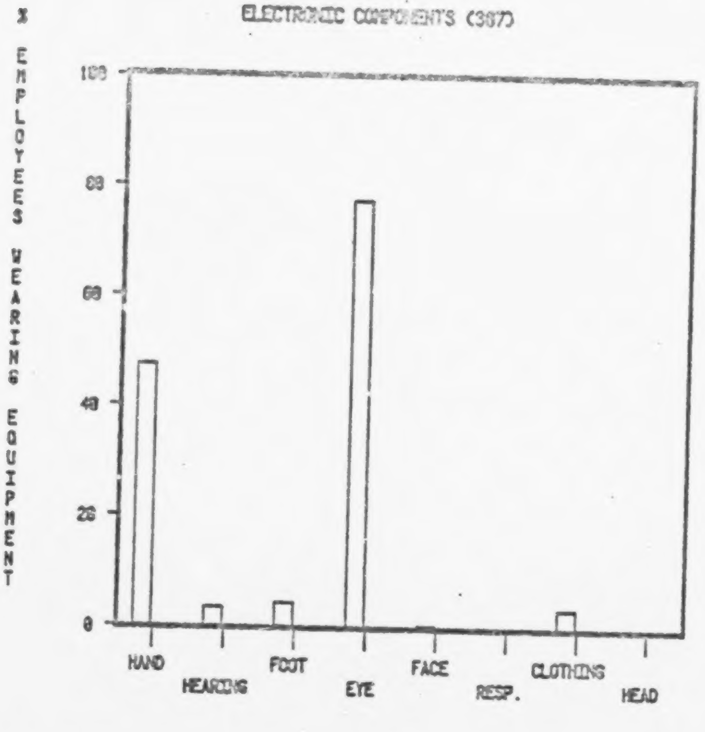
ELECTRIC LIGHTING & WIRING EQUIPMENT (364)

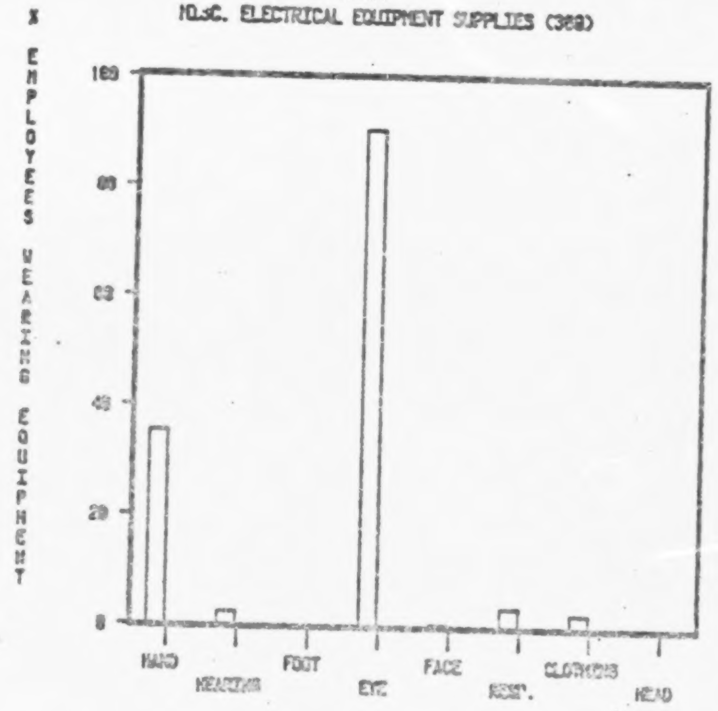


COMMUNICATION EQUIPMENT (366)

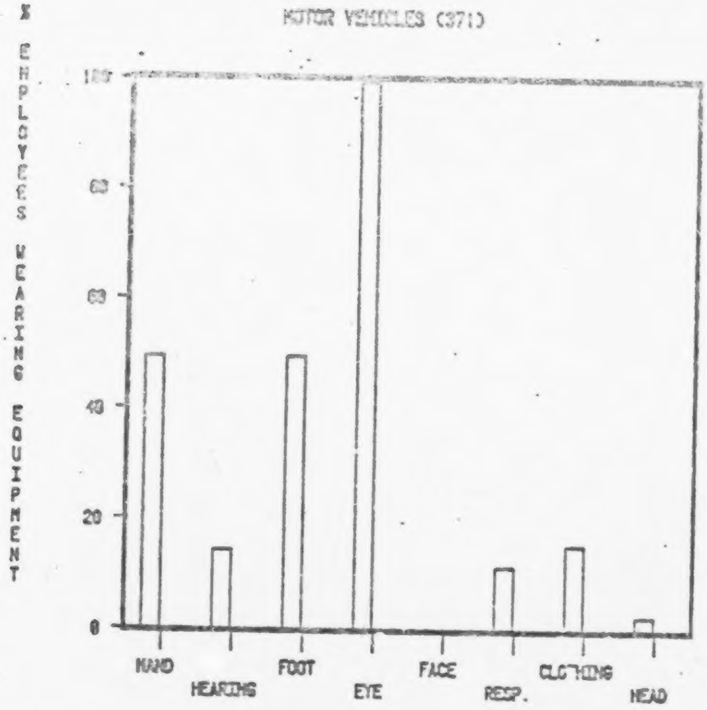


ELECTRONIC COMPONENTS (367)



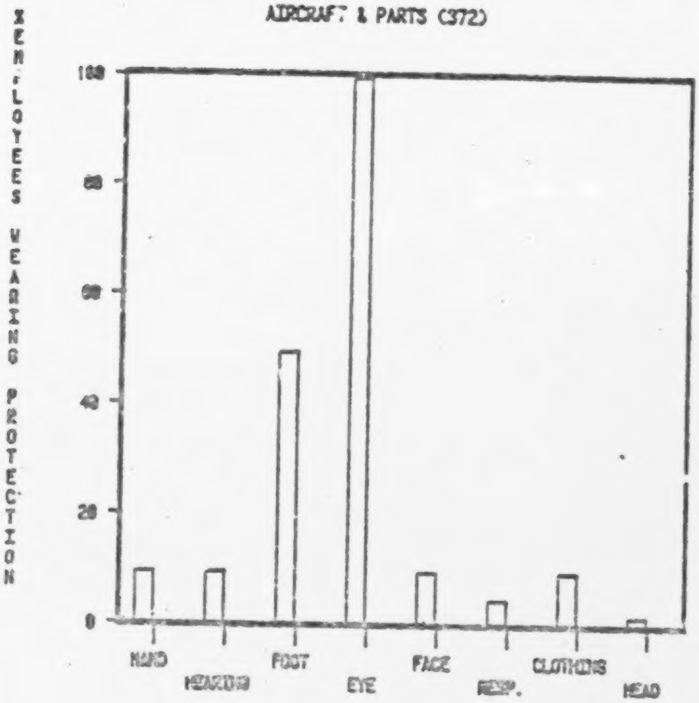


MISC. ELECTRICAL EQUIPMENT SUPPLIES (369)

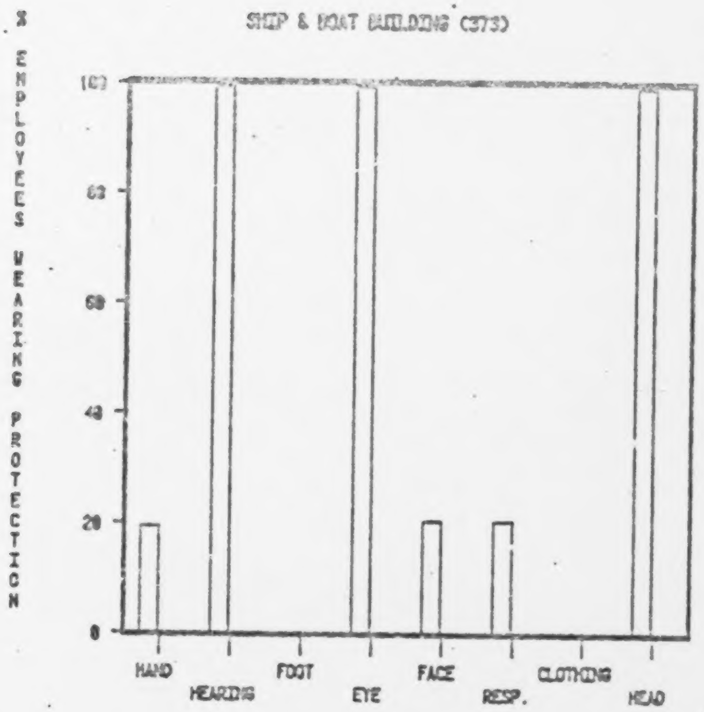


MOTOR VEHICLES (371)

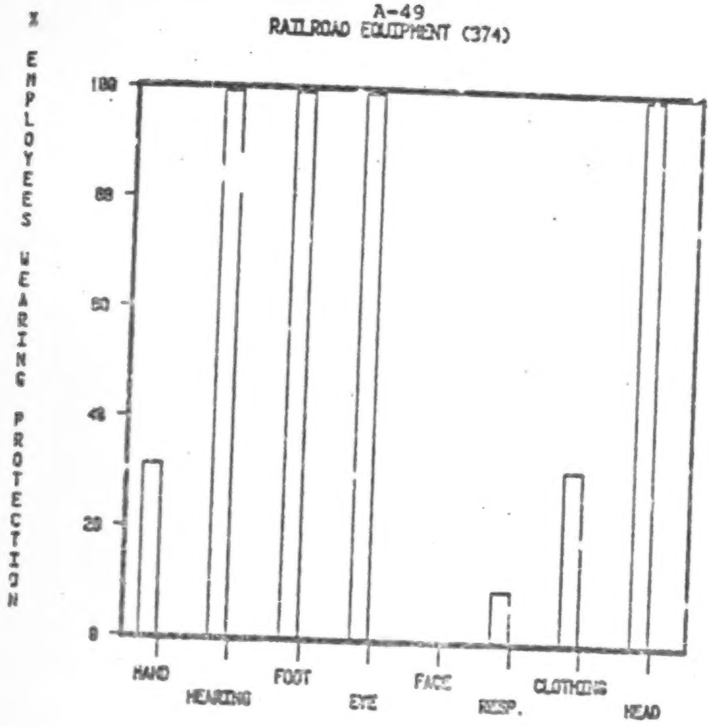
AIRCRAFT & PARTS (372)



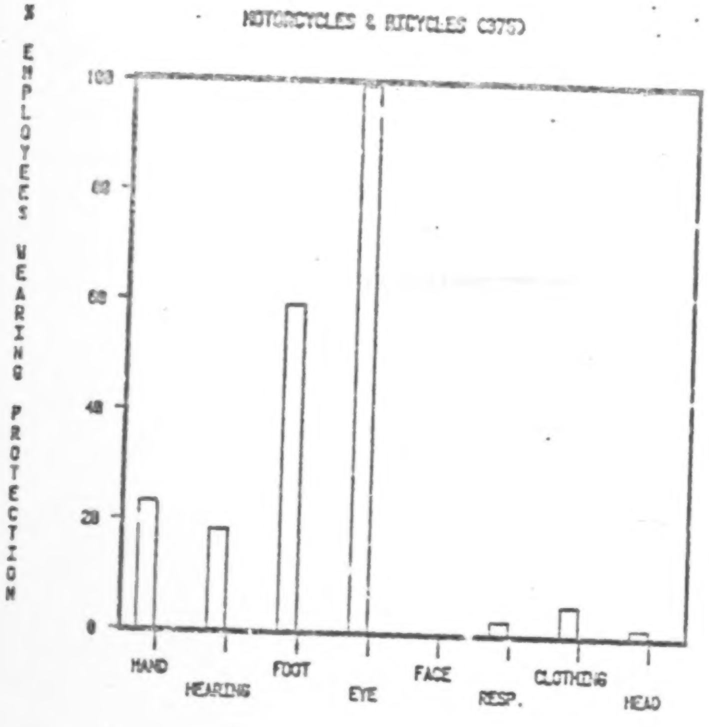
SHIP & BOAT BUILDING (373)



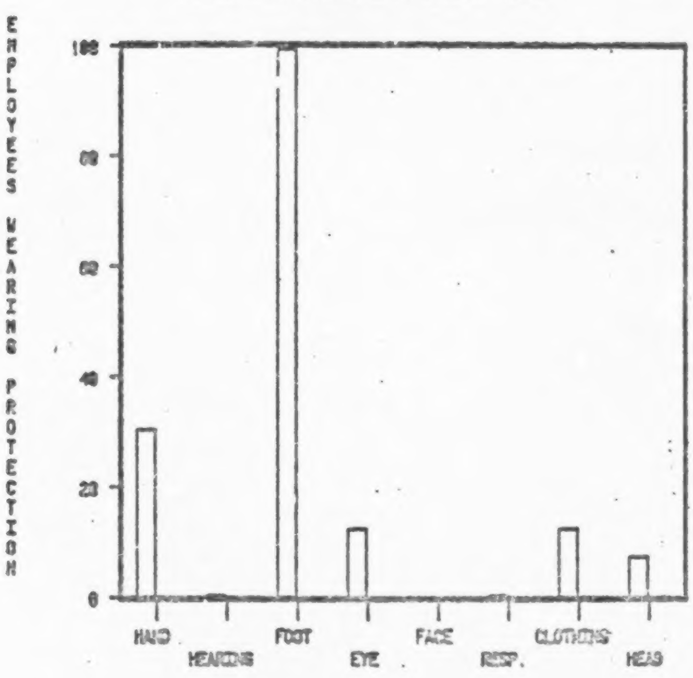
RAILROAD EQUIPMENT (374)

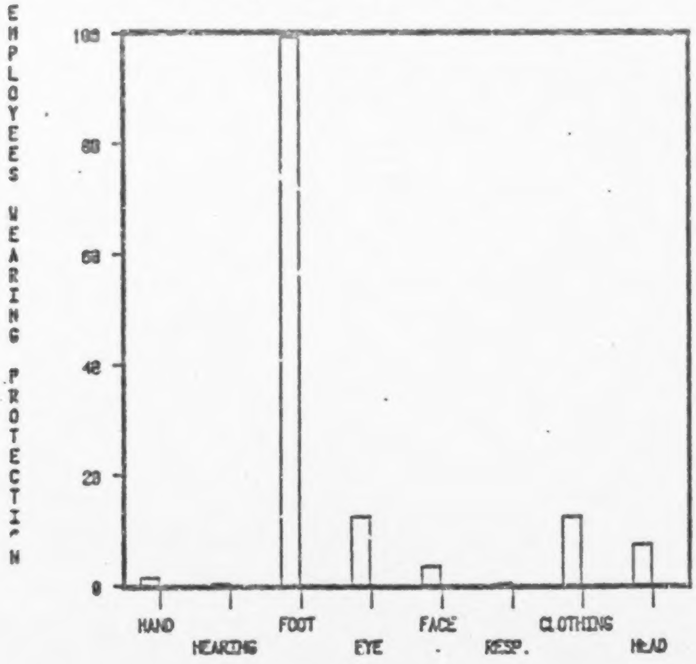


MOTORCYCLES & BICYCLES (375)



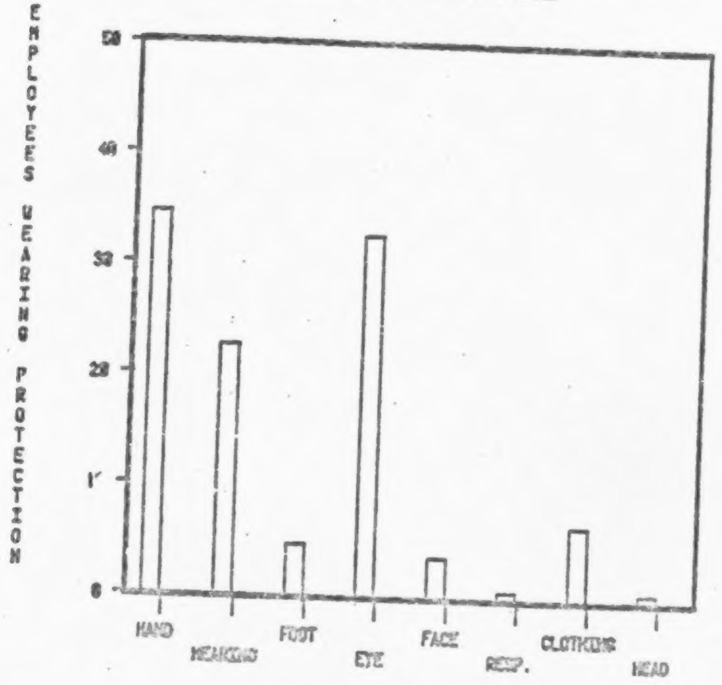
A-50


MISC. TRANSPORTATION EQUIPMENT (379)

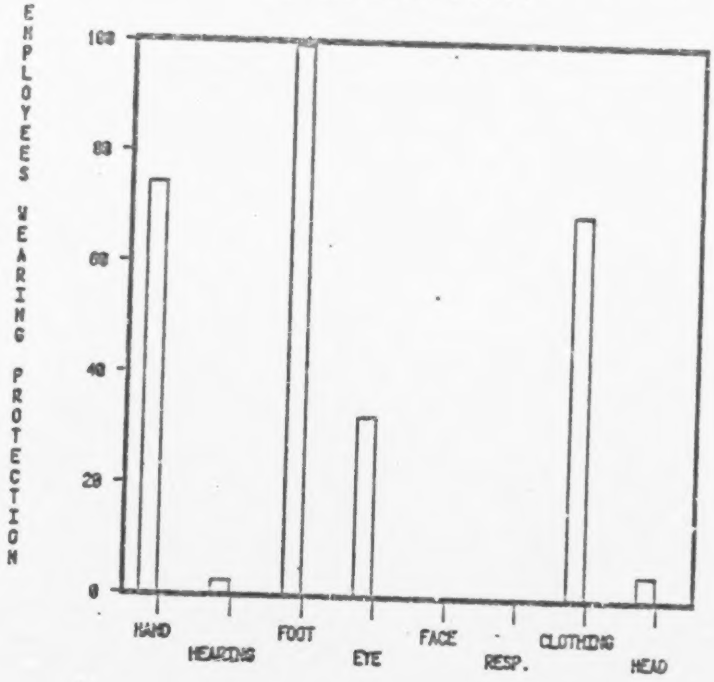

ENGINEERING, SCIENTIFIC INSTRUMENTS (381)

A-50

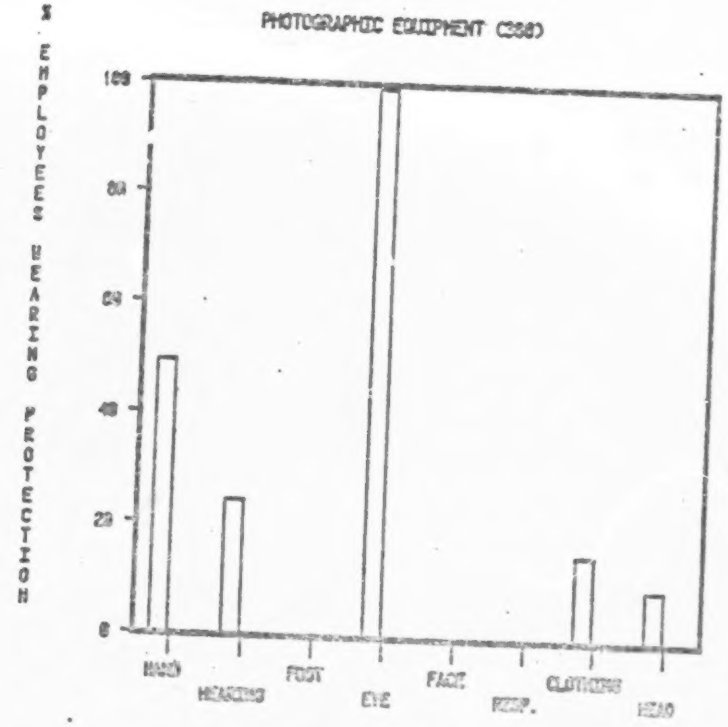
MEASURING & CONTROL DEVICES (382)



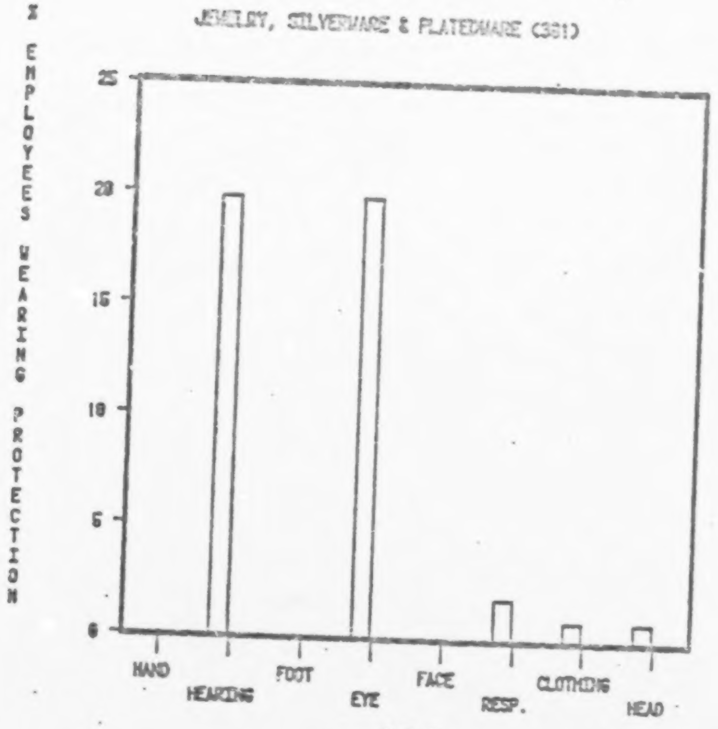
MEDICAL INSTRUMENTS (384).



PHOTOGRAPHIC EQUIPMENT (380)

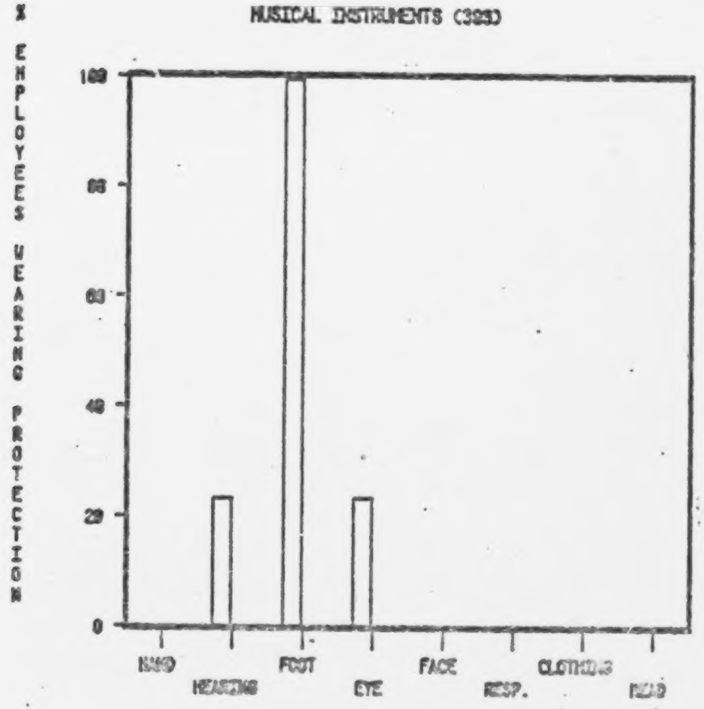


JEWELRY, SILVERWARE & PLATEWARE (381)

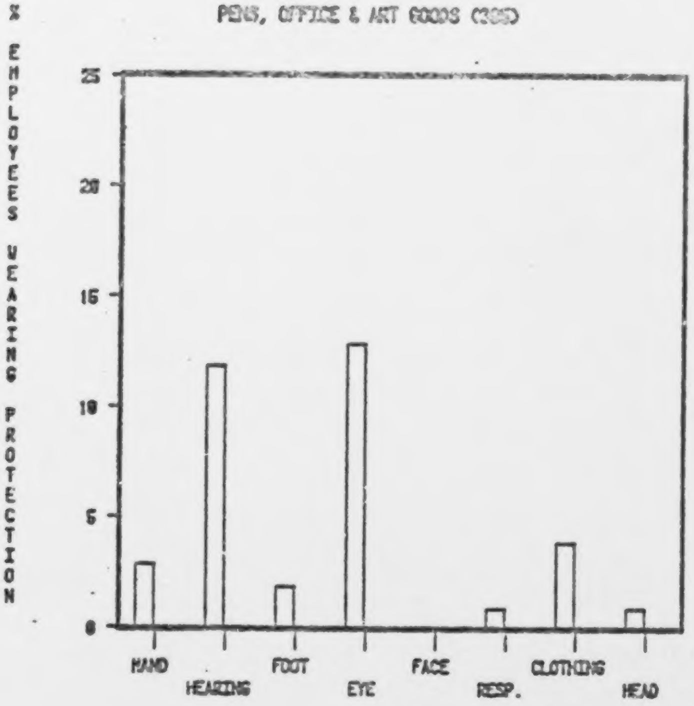


A-52

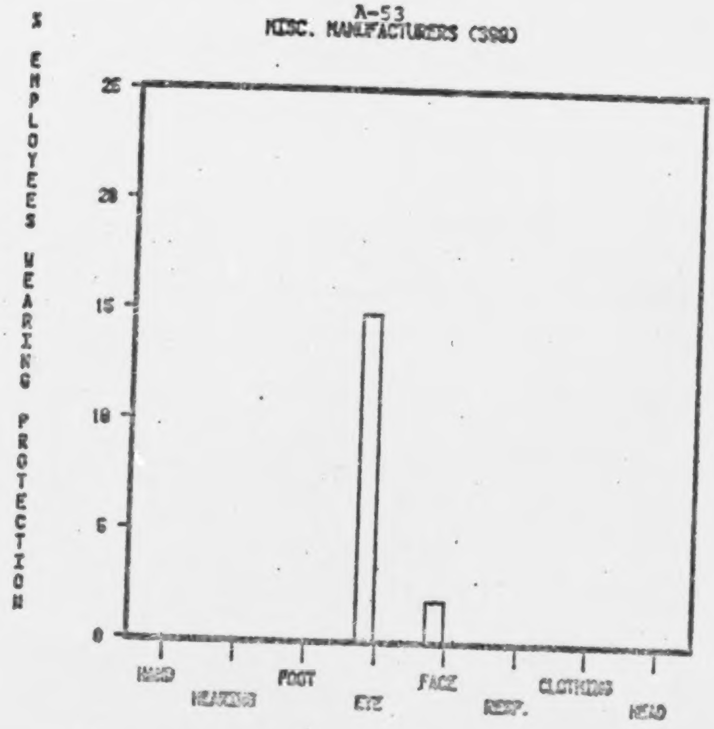
MUSICAL INSTRUMENTS (393)



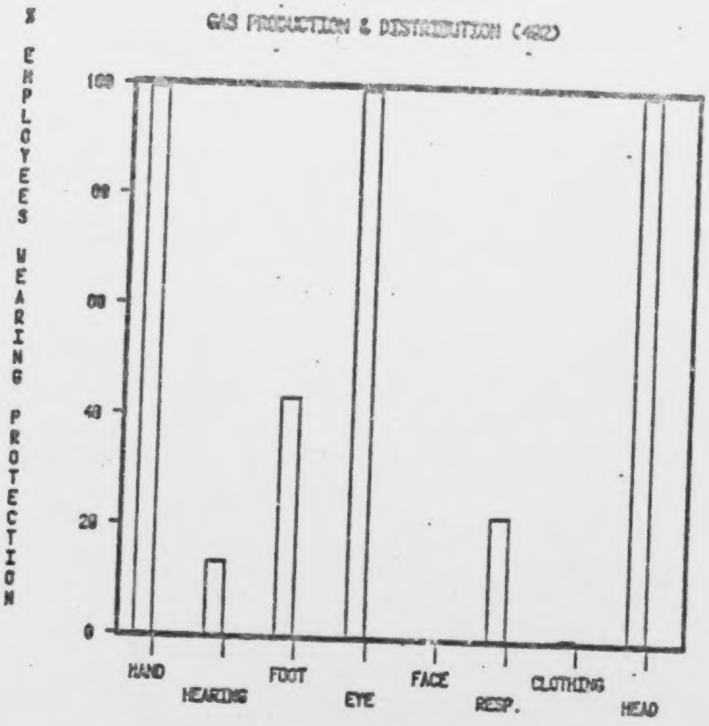
PENS, OFFICE & ART GOODS (395)

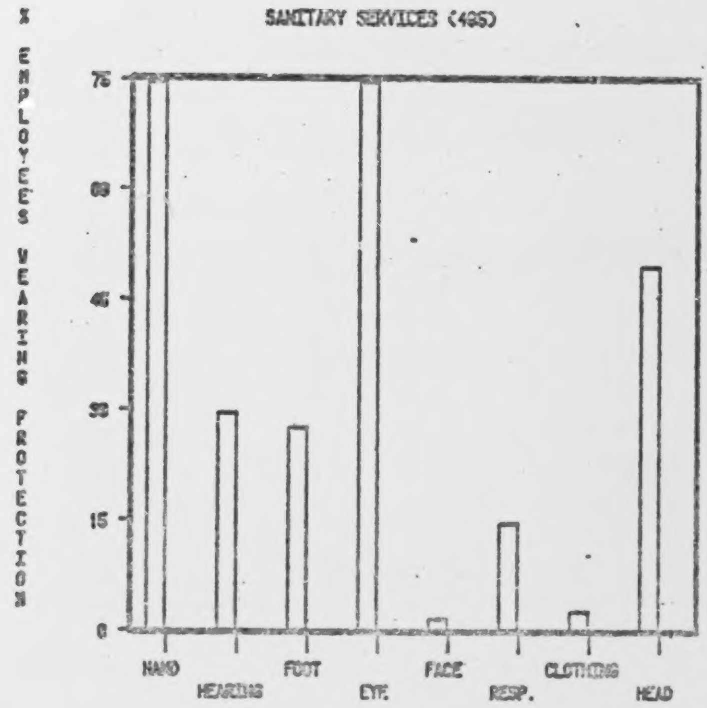


MISC. MANUFACTURERS (399)



GAS PRODUCTION & DISTRIBUTION (492)




SANITARY SERVICES (495)
% EMPLOYEES WEARING PROTECTION
75
60
45
30
15
0
HAND
HEARING
FOOT
EYE
FACE
RESP.
CLOTHING
HEAD

REPORT ON WORKPLACE PROTECTIVE EQUIPMENT AND CLOTHING -

RESPONSE TO OTA QUESTIONS

Prepared for

OFFICE OF TECHNOLOGY ASSESSMENT

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Further explanation of specific sections of the "Report on Workplace Protective Equipment and Clothing" is provided to address the questions raised by the Office of Technology Assessment (OTA) and to clarify certain points related to estimates and projections, descriptive statements and other information contained in the report.

Response to General Comments

As requested by OTA, copies of product literature describing the protective equipment and clothing offered by the major manufacturers are included in Appendix I.

In preparing the report, manufacturers, distributors and users of the equipment were surveyed. The users of the equipment were contacted to gain a general indication of the market penetration of protective equipment and clothing in the major industries. As described in the report, users of personal protective equipment and clothing in such industrial sectors as agriculture, forestry, mining, construction, manufacturing and public utilities were selected. Each of these sectors include a number of standard industrial classification (SIC) codes. Users classified under the following 30 two-digit SIC codes were contacted in this survey:

Forestry (08)
Metal Mining (10)
Anthracite Mining (11)
Bituminous Coal and Lignite Mining (12)
Oil and Gas Extraction (13)
Nonmetallic Minerals Except Fuels (14)
General Building Contractors (15)
Heavy Construction Contractors (16)
Special Trade Contractors (17)
Food and Kindred Products (20)
Tobacco Manufacture (21)
Textile Mill Products (22)
Apparel and Other Textile Products (23)
Lumber and Wood Products (24)
Furniture and Fixtures (25)
Paper and Allied Products (26)
Printing and Publishing (27)
Chemicals and Allied Products (28)
Rubber and Miscellaneous Plastics Products (30)
Leather and Leather Products (31)
Stone, Clay, and Glass Products (32)
Primary Metal Industries (33)
Fabricated Metal Products (34)
Machinery, Except Electrical (35)
Electric and Electronic Equipment (36)
Transportation Equipment (37)
Instruments and Related Products (38)
Miscellaneous Manufacturing Industries (39)
Electric, Gas and Sanitary Services (49)

Two digit SIC code classifications are subdivided into three-digit SIC code classifications which are further subdivided into four-digit SIC code classifications. These 30 two-digit SIC code classifications contain 189 three-digit SIC code classifications and 540 four-digit SIC code classifications.

The information contained in Section VI and in the Appendix of the report was based solely on these primary source contacts because in the past no study of the market penetration of protective equipment and clothing in the various industry classifications was conducted.

Users were questioned concerning the percentage of employees required to wear the equipment, the specific types of equipment worn, the replacement rates of the specific types of equipment, the manufacturers of the equipment, and the operations which require personal protective equipment or clothing. These questions were contained in a form letter that was mailed to over 6,800 companies in these 540 four-digit SIC code classifications. In addition to the information obtained from the respondents of the mail survey, nearly 200 companies were surveyed by telephone.

The response rates of the nearly 7,000 companies contacted for information concerning the use of protective equipment and clothing are shown as follows:

SIC Code	Total Employment of the Industry	# of Companies Responding	Total Employment of the Companies Responding	% of Total Industry Employment
08 Foresty	NA	8	1,132	--
10 Metal Mining	97,500	8	2,789	3
11 Antracite Mining	3.400	2	519	15
12 Bituminous Coal	244,300	2	1,377	1
13 Oil & Gas Extraction	552,000	3	5,885	1
14 Nonmetallic Minerals	122,500	15	2,372	2
15 General Building Contractors	1,212,900	3	1,795	<1
16 Heavy Construction Contractors	921,800	6	8,825	1
17 Special Trade Contractors	2,263,900	5	2,825	<1
20 Food & Kindred Products	1,710,800	20	16,614	1
21 Tobacco Manufacture	69,200	2	600	1
22 Textile Mill Products	852,700	15	46,069	5
23 Apparel and Other Textile Products	1,265,800	7	2,916	<1
24 Lumber & Wood Products	690,300	7	6,702	1
25 Furniture & Fixtures	468,800	5	2,009	<1
26 Paper and Allied Products	694,000	12	9,255	1
27 Printing and Publishing	1,258,300	9	13,475	1
28 Chemicals and Allied Products	1,107,400	12	24,473	2
29 Petroleum & Coal Products	196,600	1	500	<1
30 Rubber & Miscellaneous Plastics Products	730,700	4	46,300	6
31 Leather & Leather Products	232,600	2	1,000	<1
32 Stone, Clay, and Glass Products	665,600	11	6,384	1
33 Primary Metal Industries	1,144,100	18	44,500	4
34 Fabricated Metal Products	1,609,000	16	16,650	1
35 Machinery, except Electrical	2,497,000	12	18,648	1
36 Electric and Electronic Equipment	2,103,200	19	40,747	2
37 Transportation Equipment	1,875,300	8	54,806	3
38 Instruments and Related Products	708,500	9	38,950	5
39 Miscellaneous Manufacturing Industries	419,3000	7	5,945	1
40 Railroad Transportation	535,700	10	8,053	2

The following listing of company names is the one that accompanied the report. These manufacturers, users, and distributors were the companies who were contacted specifically to obtain information relating to the last three tasks which were contained in Sections III and IV of the report, namely:

1. A summary of the major user complaints about respirators and a description of how information about user satisfaction or dissatisfaction flows from the users to the manufacturers of respirators and laminar flow helmets.

2. New manufacturers entering the respirator and laminar flow helmet market in response to user dissatisfaction with current products.

3. A description of current research and development activities aimed at improving respirators and laminar flow helmets, including an examination of whether the research and development was from the manufacturer's own initiative or in response to user complaints and wants.

MANUFACTURERS CONTACTED

American Optical Corporation	Southbridge, MA
Bendix Corporation	Largo, FLA
Glendale Optical Co., Inc.	Woodbury, NY
International Safety Instruments, Inc.	Lawrenceville, GA
Mine Safety Appliances Co.	Pittsburgh, PA
National Draeger, Inc.	Pittsburgh, PA
National Mine Service Co.	Pittsburgh, PA
Norton Co.	Cranston, RI
Pulmosan Safety Equipment Corp.	Flushing, NY
Racal Airstream Inc.	Rockville, MD
Robertshaw Controls Co.	Anaheim, CA
Scott Aviation	Lancaster, NY
Sellstrom Manufacturing Co.	Palatine, IL
Survivair, Div. of U.S. Divers	Santa Ana, CA
3M Co.	St. Paul, MN
U.S. Safety Service and CESCO	Kansas City, MO
Willson Safety Products	Reading, PA

USERS CONTACTED

Alumax of South Carolina, Inc.	Goose Creek, SC
American Buildings Company	Aufaula, AL
Binney & Smith	Easton, PA
Bendix Corporation, Energy Controls Div.	South Bend, IN
Combustion Engineering	Newington, NH
Dow Chemical Co.	Midland, MI
Dravo Corporation	Marietta, OH
East Columbia Basis Irrigation District	Othello, WA
Eastman Gelatine Corporation	Peabody, MA
Firestone Synthetic Rubber	Akron, OH
Goodyear Tire & Rubber	Akron, OH
GAF Corporation	Binghamton, NY
G.O. International	Houston, TX
General Motors Corp., Cadillac Motor Div.	Detroit, MI
General Motors Corp., Chevrolet Tonawanda Motor Div.	Buffalo, NY
Green Bay Metropolitan Sewerage District	Green Bay, WI
Harley Davidson	Milwaukee, WI
Gulf Oil Corporation	Philadelphia, PA
Harris Metals, Inc.	Racine, WI
Invirex Demolition, Inc.	Huntington Station, NY
John Deer Co.	Ottumwa IA
Kurth Malting Corporation	Manitowoc, WI
Loctite Corporation	Newington, CT
Metropolitan St. Louis Sewer District	St. Louis, MO
Michigan Consolidated Gas Co.	Detroit, MI

DISTRIBUTORS CONTACTED

G.T. Safety	Rhode Island
Cadillac Plastic & Safety	New Jersey
Industrial Safety Supply	Connecticut
Merriam Graves	Massachusetts
Safety and Supply	Washington

In determining the market size and market shares in the different segments of the protective equipment and clothing market, nearly 140 manufacturers of protective equipment and clothing were contacted. The degree of cooperation of these manufacturers in responding to questions about market size, growth rate, market penetration of imports, market shares, new R&D, and new opportunities for manufacturers varied.

Manufacturers were not asked to comment on what the impetus to competition was in the industry, but it seems probable that the factors mentioned (price, effectiveness, durability and comfort) are the most important.

As mentioned in the report, the market segments in which imports have experienced a very significant degree of penetration are hand protection (28% of fabric gloves, 73% of leather palm, 17% of leather, 5.6% of supported and unsupported), protective clothing (nearly half of the rainwear and chemical resistant market) and PVC footwear (25% of the molded footwear). For the most part, it seems that the areas where the imports have had the greatest penetration, i.e. gloves and clothing, are not governed by ANSI standards at present. Since users and distributors were not asked to compare U.S. products with products of other countries, a valid comparison cannot be made except to say that some of these products, such as gloves and clothing, are less expensive.

Regulations for testing and certifying respirators are contained in 30 CFR Parts 11-14. A copy of the regulations is provided in Appendix II. NIOSH certifies all types of respirators but no other types of protective equipment. The Institute is considering changes in the respiratory certification program and since these possible changes are still being reviewed internally, no information could be disclosed. By the end of the year, this information may become available. At present, NIOSH does all of the testing of respirators except for testing for extrinsic safety (use in explosive areas). MSHA tests for extrinsic safety and tests for coal mine self contained rescuers.

In preparing the report it was discovered that U.S. manufacturers do supply some protective equipment to Canada and other countries; however, a detailed discussion on the size of the foreign market, the share held by U.S. manufacturers and the standards set by each of these countries was beyond the scope of this report.

Likewise, time did not permit a detailed study of the efficacy of protective equipment and testing methods to evaluate the equipment. Testing procedures may be obtained for the ANSI testing standards listed in Section II of the report. NIOSH publishes information on the equipment models that have been certified.

All of the major manufacturers of respirators were contacted and were asked to describe current research and development activities. All of the information that these companies were willing to offer is summarized in the discussion on research and development in respirators in Section IX of the report. Information on expenditures on R&D, incentives for manufacturers to go beyond ANSI standards, and the transfer of technology from other fields of manufacture to the protective devices industry would require further research and would be dependent on the knowledge, experience and cooperation of the respirator manufacturers.

Specific Comments

The Office of Technology Assistance (OTA) has requested further clarification of a number of specific statements contained in the report. These comments will be treated individually by summarizing the comment, listing the page of the report which contains the statement in question, and clarifying the statement to the best degree possible.

1. On page ii, the source of information in paragraphs 1 and 2 and the table at the bottom of the page was questioned. This information was obtained from a survey conducted by Springborn Management Services, Inc.

2. On page iii, paragraph 1, the term significant penetration of the market was questioned. This refers to the fact that some markets are saturated with only slight growth expected.

3. On page 1, paragraph 1, it was requested that the agency responsible for classifying hazardous atmospheres be named. OSHA regulates the level of toxic substances in the workplace that are acceptable.

4. On page 1, paragraph 2, it was asked to clarify the three types of respirators. The three types of respirators referred to are air-purifying and the two types of atmosphere-supplying devices, the supplied air respirators and self-contained breathing apparatus. Actually, there are really two general types, air-purifying and atmosphere supplying.

5. In response to the question, "are filters attached to the facepiece in powered air-purifying respirators" described on page 1, paragraph 4, the 3M Co. product is described as the only approved high efficiency powered air purifier with the filter in the helmet. The MSA powered air purifying respirator which is attached to a facepiece is described as belt mounted (see product literature).

6. The question was raised about the distinction between a mask and a helmet on page 2. Powered air purifying helmets are designed to provide face, head and respiratory protection, whereas powered air purifying respirators are designed to provide respiratory protection.

7. Efficiency was described by one NIOSH spokesperson as "mg of dust pulling into the filters over the amount that leaks out of it". The source for the information on page 3, paragraph 1, on the 80–90% efficiency of dust filters was obtained from "A Guide to Industrial Respiratory Protection," published by NIOSH. On page 3, paragraph 1, NIOSH and MSHA are responsible for approving respirators. OSHA requires that approved respirators be used if they are available.

8. On page [illegible], paragraph 2, single-use respirators or disposible respirators may be disposed of after each use, or when damaged, and must be discarded when the resistance becomes excessive from accumulation of the contaminant.

9. On page 6, paragraphs 2 and 3, the information on leakage of closed circuit SCBA during normal usage was obtained from NIOSH's "A Guide to Industrial Respiratory Protection". The publication provided the following description of the devices:

> "These devices are designed primarily for 1 to 4 hour use in oxygen-deficient atmospheres such as might be encountered during mine rescues. They have been used thus since the early 1900's when the Gibbs and McCaa devices were developed. The designs have not changed much since then, a significant commentary on their acceptance and good performance. NOTE: 30 CFR Part 11 approves for mine rescue only devices that give 1 hour or more performance. Devices that give 30-min or longer performance may be approved for auxiliary mine rescue service."
>
> "Closed-circuit devices are not a cure-all: there are design features that restrict their use. Because negative pressure is created in the facepiece during inhalation, there is increased leakage potential. Therefore, the devices should be used in atmospheres immediately hazardous to life and health only when their long-term use capability is necessary, as in mine

rescue. They should not be used in preference to pressure demand SCBAs for short times in immediately hazardous atmospheres. For use in oxygen-deficient atmospheres over a long period, these devices are ideal. For 1/2 hour or less, in highly toxic atmospheres immediately hazardous to life, a positive pressure open-circuit SCBA is recommended."

10. On page 7, the information on the service time of open circuit pressure-demand and demand SCBA was also obtained from NIOSH's "A Guide to Industrial Respiratory Protection". The following statement is contained in the publication:

    "Contrary to common belief, the pressure-demand SCBA has the same service time as a demand version of the same device, if it seals well on the wearer's face. Any leakage increases air consumption and decreases service time. A FACEPIECE WHOSE EXHALATION VALVE IS DESIGNED FOR DEMAND OPERATION CANNOT BE USED WITH A PRESSURE DEMAND REGULATOR AS AIR WILL FLOW CONTINUALLY AND QUICKLY EXHAUST THE AIR SUPPLY."

    Usage of air in both is determined by the user's breathing action, but pressure demand devices have an exhalation valve that maintains positive pressure and opens only when the pressure exceeds a certain value.

11. The hose mask described on page 7, paragraph 4, differs from a continuous flow airline respirator. A hose mask with a blower is categorized in 30 CFR Part 11 as Type A and without a blower as Type B. The maximum requirements for the length of hose is detailed in 30 CFR Part 11, Subpart J, 11-124-7 (See Appendix II).

12. It was requested that the term "bump caps", used on page 8, be defined. Bump caps protect workers from bumps or lacerations but not from falling or flying objects. These lightweight hard caps do not meet any federal standards for industrial head protection.

13. On pages 13-16, the definitions for the terms "excellent" and "good" were questioned along with the name of the organization who performed the

testing. To respond to these questions, some glove manufacturers supply in their product literature a listing of the commonly used chemicals and the degree of protection afforded by different types of gloves, to serve as general guidelines. The information in Exhibit 1-6 was obtained from product literature supplied by Monte Work Gloves, Mabern, Mississippi, described as a selection list for coated gloves.

14. On page 17, paragraph 2, the designation of Viton as the only glove material not easily permeated by solvent was questioned since the gloves in Exhibit 1-6 were described as providing excellent protection against certain chemicals. A NIOSH study concluded that out of 11 gloves, Viton was the only one able to withstand permeation by PCB's for up to an hour. The following tables were taken from the NIOSH report, "Permeation of Protective Garment Material by Liquid Halogenated Ethanes and a Polychlorinated Biphenyl," NIOSH Publication # 81-110. (See following tables.)

15. On page 17, paragraph 5, the second sentence should read: Guards to protect the metatarsal, the toes and/or the legs are manufactured of aluminum, steel, fiber, or plastic. On page 17, paragraph 6, the units for 25,000 and 500,000 are ohms.

16. On page 18, this statement refers to trends in more styles for women, not to size and quantity.

17. In response to certain questions raised about disposable clothing mentioned on pages 19, 20 and 22. Tyvek is impermeable to most chemicals except certain solvents, PCBs and high concentrations of sulfuric acid. The DuPont Company has provided information on the impermeability of the material. (See Appendix III.) Saranex and other materials are used to coat Tyvek to provide better protection. Usage of the Saranex coated fabric depends on the chemical since it may only be used for a short period of time against certain chemicals. Tyvek is not resistant to radioactivity per se but acts as a barrier to particulate contaminated with radioactivity such as dust. (See DuPont information in Appendix III.)

TABLE IV

1,2-DICHLOROETHANE PERMEATION RATE PROPERTIES OF PROTECTIVE GARMENT MATERIALS

	Thickness (mils	mm)	Breakthrough* Time (min)	Normalized Breakthrough Time (min mil⁻¹)	Diffusivity (cm²/min⁻¹)
A. Homogeneous, Nonbonded Materials					
Butyl rubber	(22	0.56)	140	6.36	3.74 × 10^{-8}
Neoprene rubber latex	(23	0.58)	20	0.87	23 × 10^{-8}
Nitrile rubber latex	(8	0.20)	2.5	0.31	27 × 10^{-8}
Nitrile rubber, milled	(12	0.30)	2.5	0.21	60 × 10^{-8}
Polyethylene (medium density)	(2	0.05)	2.3	1.15	2 × 10^{-6}
Poly(vinyl alcohol) unsupported	(15	0.38)	22	1.47	11 × 10^{-9}
Surgical rubber latex	(8.	0.20	1.5	0.19	45 × 10^{-8}
Teflon	(2	0.05)	—	—	—
Crumpled	—		80	43	0.06 × 10^{-8}
Unwrinkled	—		>1440	>720	<3 × 10^{-8}
Viton	(10	0.254)	820	82	<0.005 × 10^{-8}
B. Coated/Bonded Materials					
Butyl-coated nylon (Mil C-12189)	(15	0.38)	70	4.7	3.5 × 10^{-8}

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*Breakthrough time defined as that time following challenge when the permeation cells aqueous phase concentration reached 8 ppm.

TABLE V

1,1,1-TRICHLOROETHANE PERMEATION RATE PROPERTIES FOR PROTECTIVE GARMENT MATERIALS

	Thickness (mils mm)	Breakthrough[a] Time (min)	Normalized Breakthrough Time (min mil^{-1})	Diffusivity (cm^2 min^{-1})
A. Homogeneous, Nonbonded Materials				
Butyl rubber	(22 0.56)	60	2.72	8.71×10^{-6}
Neoprene rubber latex	23 0.58)	45	1.96	12.5×10^{-6}
Nitrile rubber latex	(8 0.20)	30	3.75	2.2×10^{-6}
Polyethylene (medium density)	(2.0 0.05)	3	1.5	1.4×10^{-6}
Surgical rubber latex	(8 0.20)	4	0.50	16.7×10^{-6}
Viton	(10 0.25)	>1440	>144	$<0.07 \times 10^{-6}$
B. Coated/Bonded Materials				
Butyl-coated nylon (Mil C-12189)	15 0.38)	25	1.67	10×10^{-6}
Polyethylene-coated Tyvek	(5 0.13)	—	—	—
Tyvek toward water	—	10	2.0	2.8×10^{-6}
Polyethylene toward water	—	12	2.4	2.3×10^{-6}
Polyurethane-coated nylon	(4 0.10)	2	0.5	8.3×10^{-6}
Poly(vinyl chloride)-coated nylon	(10 0.26)	3	0.3	33×10^{-6}

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[a] That time at which the aqueous phase 1,1,1-trichloroethane concentration exceeded 2 ppm.

TABLE VI

1,1,2-TRICHLOROETHANE PERMEATION RATE PROPERTIES FOR PROTECTIVE GARMENT MATERIALS

	Thickness (mils mm)	Breakthrough[a] Time (min)	Normalized Breakthrough Time[a] (min mil^{-1})	Diffusivity (cm^2 min^{-1})
A. Homogeneous, Nonbonded Material				
Butyl rubber	(22 0.56)	50	2.27	10×10^{-6}
Neoprene rubber latex	(23 0.58)	7	0.30	80×10^{-6}
Nitrile rubber latex	(8 0.20)	2	0.25	33×10^{-6}
Polyethylene (medium density)	(2 0.05)	3.5	1.8	1.2×10^{-6}
Poly(vinyl alcohol), unsupported	(15 0.38)	15	1.0	16×10^{-6}
Surgical rubber latex	(9 0.23)	1	0.11	88×10^{-6}
Teflon	(2 0.05)	—	—	—
Crumpled	—	175	87	0.024×10^{-6}
Unwrinkled	—	>1440	>720	$<0.0029 \times 10^{-6}$
Viton	(10 0.25)	>1440	>144	$< 0.072 \times 10^{-6}$
B. Coated/Bonded Materials				
Butyl-coated nylon (Mil C-12189)	(15 0.38)	45	3	5×10^{-6}
Polyurethane-coated nylon	(4 0.10)	<1	< 0.25	$>17 \times 10^{-6}$

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[a] That time following test initiation when 1,1,2-trichloroethane was observed at a concentration of 1 ppm in the aqueous phase of the permeation cell.

TABLE VII

POLYCHLORINATED BIPHENYL (PCB)[a]
PERMEATION RATE PROPERTIES FOR PROTECTIVE GARMENT MATERIALS

	Thickness (mils mm)		Breakthrough[b] Time (min)	Normalized Breakthrough Time (min mil^{-1})	Diffusivity (cm^2 min^{-1})
A. Homogeneous, Nonbonded Materials					
Butyl rubber	(22	0.56)	2.5	0.114	209 × 10^{-8}
Neoprene rubber latex	(23	0.58)	0.6	0.022	1121 × 10^{-8}
Nitrile rubber latex	(8	0.20)	1	0.125	67 × 10^{-8}
Polyethylene (medium density)	(2	0.05)	0.8	0.40	5 × 10^{-8}
Poly(vinyl alcohol), unsupported	(11	0.28)	0.6	0.05	218 × 10^{-8}
Surgical rubber latex	(8	0.20)	0.3	0.0375	222 × 10^{-8}
Viton	(10	0.254)	60	6.0	2 × 10^{-8}
B. Coated/Bonded Materials					
Butyl-coated nylon (Mil C-12189)	(15	0.38)	3	0.20	80 × 10^{-8}
Polyurethane-coated nylon	(4	0.10)	0.5	0.125	33 × 10^{-8}
Poly(vinyl chloride)-coated nylon	(10	0.25)	0.5	0.05	203 × 10^{-8}

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[a] Aroclor 1254.

[b] That time following test initiation when a PCB concentration of 1 ppm was observed present in the aqueous phase of the permeation cell.

18. The description of Zetex on page 20 was obtained through product literature provided by the manufacturer. Zetex is described as being comparable or lower in price than asbestos for clothing but the type of Zetex material used for gloves and mittens is 10-20% higher in cost than the grade of asbestos used for that purpose.

19. The information on page 21, Exhibit 1-8 was obtained from Rainfair, Inc., Racine, WI in product literature supplied by the company.

20. On page 23, paragraph 4, visitor's eyewear is lightweight, inexpensive eye protection (goggles and spectacles) for plant visitors or personnel who enter the work area infrequently to protect these individuals from flying particles. Visitors eyewear is not suitable for production workers. The equipment may be cleaned for use or disposed of after use.

21. On page 26, paragraph 3, the regulations used by NIOSH to test respirators may be based partly on old ANSI standards.

22. On page 27, paragraph 2, for more information on ISEA contact:

    Mr. Frank Wilcher, Jr.
    Executive Director
    Industrial Safety Equipment Association
    1901 N. Moore Street
    Arlington, VA 22209

23. Definitions for transmittance, safety plates and filter plates used on page 29 were requested. The welding helmets include a number of plates with different functions. Included in these are:

    a) the welding or filter plate which provides protection by absorbing radiant energy;

    b) the cover plate which protects against hot splatter;

    c) the safety plate which provides greater impact resistance.

A more transparent cover plate allowing greater percentage of transmittance is desirable since the function of this plate does not include protecting against radiant energy. Transmittance is the fraction of radiant energy that, having entered a layer of absorbing material, reaches its farthest boundary.

24. On page 30, paragraph 1, public review refers to the period of time in which ANSI accepts comments from the public on a standard that has been approved and revised.

25. On page 35, paragraph 1, Plasmed molds the ear plugs and sells them to the hearing protection suppliers.

26. On page 36, paragraph 2, the significance of the three companies being jointly owned is that Parmalee supplies lenses and the other two are suppliers of eye protection.

27. In paragraphs 1 and 2 on page 38, "outsources" refers to the obtaining of the product sold by the protective equipment supplier from another manufacturer.

28. The last heavy heading in Exhibit 3-6 on page 38 should read "Both Leather and Rubber and/or PVC."

29. In paragraph 5 on page 39, David Clark Co. is usually recognized only as a manufacturer of hearing protection, but they do make space suits. In the second sentence, many of the disposable clothing manufacturers are only involved in manufacturing that one product line.

30. "Turnout" clothing is the protective clothing worn by firefighters.

31. The information on pages 42 and 43, including Exhibits 4-1 and 4-2, were obtained through a survey conducted by Springborn Management Services, Inc. The disposable respirators referred to are those receiving NIOSH approval. Dust masks are the unapproved protective devices used to protect against nuisance dust only. The disposable respirator market is expected to

grow at a faster rate because a disposable product is more desirable to many companies since it eliminates the need for cleaning and maintaining respirators.

32. The distributor cost is the cost that the supplier charges the distributor; user cost is the cost that the user pays the distributor. On page 48, paragraph 2, the dollar value is expected to increase with energy costs since increases in energy costs will affect material costs and manufacturing costs.

33. On page 49, Exhibit 4-7 lists costs on the distributor level. The number of units sold may be determined by dividing the market size by the average cost.

34. The source of the information on page 55, paragraph 1 was a survey conducted by Springborn Management Services, Inc.

35. On page 55, paragraph 5, the reason that prescription eyewear is replaced less frequently than plano eyewear is that the prescription wearer maintains the eyeglasses better.

36. On page 56, the costs are on the distributor level.

37. On page 61, Exhibit 4-16, "supported" refers to liquid proof gloves of rubber or synthetic material over fabric. "Unsupported" gloves are similar, but do not have fabric linings.

38. On page 64, the information was obtained through a telephone survey of manufacturers and distributors.

39. On page 70, paragraph 3, the information was obtained by contacting distributors of safety products.

40. On page 71, all of the information about discounting which was provided by the distributors contacted is included in the discussion.

41. On page 71, paragraph 4, details about any programs conducted by the Safety Equipment Distributors Association, Wacker Drive, Chicago, IL, or the Industrial Safety Equipment Association, Arlington, VA, were not obtained.

42. On page 73, these SIC codes were selected because forestry, mining, manufacturing and utilities are the industry segments where the greatest use of protective equipment was expected. A survey of the proportion of full time employees wearing the equipment vs. part time employees was too detailed for this type of survey.

43. On page 89, paragraph 4, no information was obtained on the degree of prevention of injuries in the industries requiring more than 50% of workers to wear hand protection.

44. On page 91, paragraph 5, no information more recent than the OSHA study on hearing protection that was published in 1981 was found.

45. On page 94, paragraph 4, line 1 should read: Subpart Z of 29 CFR, Part 1910 of the regulations.

46. On page 98, paragraph 2, "enforcement" by the company refers to company policy requiring the wearing of the equipment and careful monitoring by the supervisor to ensure that the equipment is being worn.

47. On page 100, Exhibit 8-1, the price deflator used to calculate constant dollars was questioned. The 1977 figure was divided by 1.398 to arrive at the current dollars figure.

48. On page 101, Exhibit 8-2, the market research firm, Predicasts, Inc., is located at 200 University Circle Research Center, 11001 Cedar Avenue, Cleveland, OH.

49. The information in Exhibit 8-2 is the size of the 1976 market as estimated by Predicasts, Inc. The estimates by Predicasts were in some cases lower than

what the Bureau of the Census actually recorded as the value of shipments for certain types of protective equipment.

50. On page 102, the rates of increase were not on an annual basis.

51. On page 103, in Exhibit 8-4, the average annual growth rates were based on the opinions of the equipment manufacturers contacted, historical data from the 1970s and expected growth in the workforce in the 1980s. The 1986 market was based on the average annual growth rate applied to the estimates of the 1981 market obtained by Springborn Management Services, Inc.

52. On page 104, paragraph 2, of the 31 users contacted, 25 stated that they had no complaints and 6 expressed some degree of dissatisfaction with respirator comfort, performance, or operation. One commented specifically about the bulkiness of SCBA.

53. On page 105, paragraph 2, since the information was obtained from a number of manufacturers and distributors, it is not possible to determine the exact number of firms who have voiced the complaints. The manufacturers were simply asked to describe some of the criticisms that users of the equipment have related to them. The Safety Department is responsible for ensuring the proper use and maintenance of the respirator.

5[illegible] [illegible] comments in page 106, paragraph 1 reflect the opinion of some manufacturers of respiratory equipment. The only details offered by the manufacturers are included in this discussion.

HEALTH AND SAFETY CONTROL TECHNOLOGIES IN THE WORKPLACE

ACCIDENT CAUSATION AND INJURY CONTROL

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INTRODUCTION:

The application of any control technology must obviously begin with an understanding of the nature and scope of the problem under consideration. The various data sources for occupational injuries and illnesses have been reviewed in an excellent paper by Karl Kronebusch which should be read prior to this paper and viewed as the starting point for this paper. Some of the major conclusions of his paper are restated briefly as follows:

(1) A number of data sources are available to describe the magnitude and distribution of occupational injuries and illnesses. The sources differ in the universes covered and the methodology used.

(2) Discrepancies exist in the various data sources regarding the incidence of fatalities and injuries in the workplace, even when attempts are made to rationalize the data because of the different methodologies used for collecting the data.

(3) Most of the data that are collected do not provide information which is sufficiently detailed to be useful in developing prevention programs.

Using point three as a springboard, the next section presents information regarding the major problems which exist in using the data currently collected for developing and implementing injury control technologies in the workplace. This section is followed by the presentation of alternative approaches to collecting injury information which will provide the data needed for developing control technologies. A discussion then follows of the major points which must be addressed in developing effective injury control technologies for the workplace. The paper is then concluded by a discussion of current trends and future innovations, noting the needs which exist for more research in order for some of the new technologies to be implemented.

INJURY DATA SYSTEMS

Current Situation/Problems:

If one considers the continuing number of accidents and injuries which occur in the workplace each year, the obvious question is why more improvement has not been possible. In some instances there are economic constraints which limit an enterprise's ability to make needed improvements in the workplace to reduce injuries. However, there are clearly many instances where accidents produce injuries which could have been prevented with little or no additional expenditures. Other constraints which prevent a reduction of injuries in the workplace must therefore also exist.

The nomenclature of occupational safety regarding accidents and injuries is sometimes confusing to one not familiar with the area. In an attempt to avoid confusion in the following sections of this paper, the reader should note the following distinctions:

Accidents are generally defined as unplanned events which occur that have the probability of causing personal injury or property damage, i.e.

the potential exists to cause personal injury or property damage, and these outcomes can be expected some proportion of the time that the unplanned event occurs.

Injuries result from accidents some proportion of the time, but not every accident causes an injury. Injuries may be minor (scratch, bruise or laceration treated by first aid) or major (worker is absent one or more days from the job; injury reported under workers compensation program).

In a study reported by Heinrich, Petersen and Roos (1980) of 5,000 cases where accidents of the same kind were compared, the following proportions were observed:

1 accident out of 330 produces a major injury (0.3 percent)
29 accidents out of 330 produce minor injuries (8.8 percent)
300 accidents out of 330 produce no injuries (90.9 percent)

These proportions give rise to the "1-29-300" rule for the *average* condition in industry. Of course, the proportions will change for one industry versus another and cannot be relied on without validation in a given industry.

In the discussions which follow, the terms "accident" or "injury accident" should be interpreted as those accidents involving an injury, usually a major one.

One of the principal constraints preventing a reduction of workplace injuries is an insufficient conceptual framework of the accident process. Ideally, analytical procedures should be applied before any system is constructed to evaluate the level of risk of injury and then design modifications made to bring the risk within acceptable limits. Even though such procedures are now routinely applied in the space program and in building military weapons systems, they are seldom applied in the occupational setting. In fact, the author is aware of military contractors who perform such analyses for the products they build, but would never think of applying the same analyses in the workplaces of their employers.

Given that analytical procedures are not applied to predict and prevent accidents and injuries, the next logical step is to follow some procedure to learn of near misses or critical incidents in the workplace and in turn use this information to make changes to reduce the continuing risk of injury. However, this approach is not followed in industry to a great extent, probably less than 25 percent of industrial enterprises have even an informal program of this type, and less than 10 percent have a formal program to collect and use such information for accident/injury prevention.

In the preponderance of industry today, the information used in injury prevention has been collected as a result of previous injury accidents which have been investigated. This approach has the obvious philosophical problem of using workers as guinea pigs or experimental subjects. Because this is the primary approach to data collection for injury prevention, numerous investigation techniques and methods have been developed in an effort to collect useful information about the causes of accidents. However, despite these efforts, there is still not enough valid and reliable data on accidental injury mechanisms to serve as a basis for informed evaluation and decision-making in developing control technologies.

Numerous needs for prevention data must be met through accident investigations. This data should meet at least the following requirements:

(1) Suggest needed changes in work methods or systems.

(2) Indicate where modifications should be made to machinery and equipment.

(3) Suggest where job training is in need of improvement.

(4) Help uncover weaknesses in organizational structure which need improvement to prevent injuries.

(5) Be compatible with the data input needs of one or more models for analyzing injury causation.

(6) Statistical comparisons of injury incidence based on comparable risks should be possible.

(7) Define research needs where current knowledge/technology is inadequate to design safer workplaces.

In addition, government agencies need data to evaluate the effectiveness of current or proposed standards and regulations in preventing injuries.

If the data currently being collected in industry today are examined, it will be found that few of the requirements listed are satisfied. There are some difficult issues which must be addressed if the situation is to be improved.

First, there is a conceptual problem of the proper approach to follow as noted earlier. Singleton (1983) has stated,

> "It is perhaps unfortunate that safety research has followed too closely the approved methodology of the physical sciences which is essentially a reductionist and iterative approach. The scientist conducts some observations, collects some data and generates a theory

which explains how and why the data are related internally. The theory is then tested by predicting what will happen in specified controlled situations. This approach can never work in relation to safety. It is not possible, either ethically or conceptually, to devise controlled situations for which accident rates have been predicted and then check the predictions by noting the real events. The classical scientific method is inappropriate in its emphasis on the central role of prediction within validation."

Singleton (1983) further notes that the basic assumption in classical science is that theories must be constructed to explain cause and effect, with the implication that an understanding of cause will allow us to predict and control the effect. He rejects this approach in safety research and suggests that the best we can ever do is monitor and try to influence a set of key parameters that affect the overall probability of accidents/injuries generally.

In contrast to Singleton's (1983) perspective, other researchers (Heinrich, 1959, Petersen, 1971, Benner, 1983) would suggest that there is an appropriate conceptional model to explain cause and effect in a direct way when accidents occur. However (Singleton (1983) is correct in noting that a model which uses a number of parameters to explain the cause of a *single* accident will not necessarily be a very good predictor of future accidents since the same set of conditions will occur infrequently.

Given such a divergence of viewpoints, it is not difficult to see why safety research has progressed so slowly. In contrast to industrial hygiene where animal studies can provide insight into the harmful

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effects of a chemical without exposing humans to such risks, it is not possible to perform similar research in the area of safety. Such a dilemma has led researchers such as Singleton (1983) to suggest that safety is best practiced like process control, i.e. the process controller is concerned with keeping such parameters as pressure, temperature and flow rate under control in a process without trying to understand all the cause and effect relationships which produce changes in these parameters. This type of thinking has led some safety researchers to suggest that workplace injuries are caused by a sudden, unexpected application of energy to a part of the body, and therefore we should concentrate on keeping this energy flow within acceptable limits. In fact, much of the safety engineering practiced today can probably be characterized as a process control model.

The reader will probably conclude that following either a process control approach or a cause and effect model exclusively is a questionable strategy. In the ultimate sense, we must proceed in safety research as the M.D. does when a new disease such as Acquired Immune Deficience Syndrome (AIDS) is encountered, i.e. control the vital health parameters of heart rate, blood pressure, digestion, etc. as well as possible according to known norms, while at the same time searching for the cause and effect explanations of how the disease spreads and how it can be cured.

Even though brief, it is hoped that the foregoing paragraphs have provided a foundation for understanding some of the major issues in developing safety control technologies which will be addressed in subsequent sections. Some of the more worrisome practical problems in collecting safety research data will now be briefly discussed.

Wide differences exist among the methods and schemes used to collect, verify and classify data taken from accident investigations. Many existing classification schemes appear to yield descriptive data about the part of the body injured and the mechanism of injury, but do not provide information about interrelationships among worker actions, equipment, environmental factors and situational events which may be related to the cause of the injury. Even when such information is collected interrelationships among variables are often lost when the data are pooled in order to serve information needs at several organizational levels. Another factor preventing the acquisition of desirable, detailed information is the wide variation among the methods by which accident/injury data is recorded and classified. The different schemes used to classify data range from full use of the American National Standards Institute (ANSI) Z16.2 Standard to modifications of Z16.2 systems, to many in-house schemes.

The ideal approach to an accident investigation should be universal, complete, and reproducible by different investigators, and the data collected easily communicated to a data base. Non-standardized approaches utilized by many accident investigators create barriers to a common understanding of causal factors, reduce the transfer of knowledge about safety countermeasures, and create injustices in the determination of the culpability of persons involved in specific accidents. An acceptable approach for data collection should describe what happened, why it happened as it did, what the investigation should encompass, what data are needed, how the acquired data is analyzed and tested for validity, explain relationships, and specify how the findings should be presented. The mechanism of investigation should be compatible with a cumulative data base which allows for a realistic utilization of the information for analysis and recommendation of specific countermeasures to reduce the incidence of accidents.

Such an approach would allow an organization to pinpoint those areas of work activity where the highest degree of risk exists and organize its resources to modify the work situation accordingly. If the system is not well designed, false impressions of problems are portrayed and the organization can place more emphasis on an area than is warranted while ignoring other more important areas.

In many accident-injury information systems there appears to be little systematic conceptualization of variables related to accidents and injuries. Human, physical and situational factors associated with accidents and injury occurrences appear to be inconsistently recorded across many existing schemes. This situation causes two major problems. First, accurate data comparisons from organization to organization become difficult, and second, individual organizations do not develop a good picture of their problems.

A properly designed and functioning system would be capable of demonstrating the human, situational, and environmental interactions associated with an accident. Only through such associations is the investigator able to gain the insight needed to understand the nature of any given accident.

The primary purpose for the collection of accident statistics is to identify probable causes of work-related injuries and illnesses so that prevention measures may be employed. This goal should dictate the methods by which the statistics are collected and analyzed. Unfortunately, accident statistics are usually compiled in a way determined by the availability of the data rather than by the requirements of causal research (Holander, 1978). Many government agencies and private sector organizations expend considerable resources to produce accident statistics. Their methods are primarily oriented towards quantifying the number of accident occurrences; number of lost-time accidents, number of minor accidents, the incidence rate, the frequency rate, and the severity rate. Typically, these measures are compared with other variables such as age, occupation, nature of accident, type of injury, and "cause" of accident. However, these reports on accident statistics rarely contain any conclusions or recommendations to enhance safety. Why then are these data compiled and published at such cost? According to Kletz (1976) the statistics are "continued out of habit when their uselessness has become apparent."

Even after accident statistics have been compiled, they may still be difficult to interpret. Usually there is no way to correct for differences in exposure between various jobs in order to make risk assessments of the dangers involved. For example, consider construction work where working on scaffolds and working in trench excavation produce many fatal accidents; however, since no information exists on how many workers or how much time is spent working on scaffolds and in trenches, it is impossible to say how dangerous these jobs are when compared to other activities. It may be that, per hour spent working, there are more accidents occurring in some other construction task.

A need may also exist to have exposure data for two ore more tasks related to one type of equipment. For example, an accident analysis of scaffold accidents (DOL, 1981) showed that 59% of the accidents occurred while working on scaffolds and 10% occurred while erecting and dismantling them. It seems likely that workers spend far more time working on the scaffold than in erecting and dismantling; thus, if the time spent ratio is greater than six to one (59% to 10%) as is the case, then the set-up and tear-down phase is more dangerous. Facts such as this should then be reflected in worker training programs and in research to design safer scaffolds. The aforementioned scaffold study also found that for ten scaffold types, 31% of all accidents involved the welded tubular type. However, this should not imply that that this type is more dangerous than other types unless it can be shown that less than 31% of all scaffolds in use are of the welded tubular type.

An example from traffic safety research may also better illustrate the importance of exposure data. Traffic accident statistics show that people over 65 years of age have very few accidents per thousand persons when compared to the overall population of drivers. From this many conclude that older drivers are safer. However, when accidents per million miles driven are calculated, it becomes clear that older drivers have more accidents per mile driven than the average driver. Thus, it should become apparent that exposure data is requisite to assigning quantitative risk values to various jobs, tasks, or occupations for the potential of accidents. The same holds true for most findings based on existing accident statistics.

As noted earlier, the majority of ongoing accident data collection systems in the U. S. are based on the ANSI Z16.2 Standard, Method of Recording Basic Facts Relating to the Nature and Occurrence of Work Injuries. This traditional approach does not adequately address the complexities of the accident phenomenon with respect to causal factors description and definition. Quoting from the ANSI Z16.2 text:

> "It is recognized that the occurrence of an injury frequently is the culmination of a sequence of related events, and that a variety of conditions or circumstances may may contribute to the occurrence of a single accident. A record of all these items unquestionably would be useful to the accident preventionist.
>
> Any attempt to include all subsidiary or related facts about each accident in the statistical record, however, would complicate the procedure to the point of impracticability. The procedure, therefore, provides for recording of one pertinent fact about each accident in each of the specific categories or classifications. To insure uniformity in the selection of items to be recorded in each category, the items are specifically defined in terms which eliminate any necessity for decision as to the relative importance of multiple items falling in the same category."

Thus, it is apparent that a system which "provides for recording of only one pertinent fact about each accident in each of the specific categories or classifications" is not likely to contribute much meaningful insight into the accident process. It is a good accounting system for administrative data, but inadequate for causal factor research. It is not surprising that the most common entry on the system's data sheet is for human error with respect to cause. This force fit of accident responsibility into the category of human fallibility with no significant data as to why the error was committed is by no means limited to the ANSI system, since others have followed a similar approach. Any system which perpetuates this idea in its approach to *data collection is likely to yield only limited information for preventing future accidents.*

TRADITIONAL APPROACH TO ACCIDENT CAUSATION

In the quest for understanding accident causes, it is essential to consider the philosophy Heinrich (1959) proposed in the mid-twenties. His basic theory of accident causation which most safety professionals have followed for decades is the domino sequence. Simply stated his premises are:

(1) Injuries are caused by accidents.

(2) Accidents are caused by unsafe acts of persons or exposure to unsafe mechanical conditions.

(3) Unsafe acts and conditions are caused by faults of persons.

(4) Faults of persons are created by the environment or acquired by inheritance.

Using this approach to accident causality, Heinrich (1959) analyzed 12,000 cases from closed-claim-file insurance records. An additional 63,000 cases were collected from the records of plant owners, giving a total of 75,000 cases which were analyzed. He noted that 25 percent of all accidents would, according to usual methods employed at the time, be charged to defective or dangerous physical or mechanical conditions. However, he proceeded to note that many accidents in the original group of 25 percent were caused either wholly or chiefly by worker failure, and only partly caused by physical or mechanical conditions. Therefore, any accident which was not *wholly caused* by physical or mechanical failure was considered to be the result of an unsafe act and classified with the original 73 percent of accidents attributed to "obviously" unsafe acts. This produced the well known figure of 88 percent of all accidents as being attributed to unsafe acts in Heinrich's approach.

At the time Heinrich made his analysis, the concepts of human factors engineering or ergonomics were not developed, so it could be expected that he would have classified a number of accidents which had some failures in man/machi-· systems design as being wholly the result of an unsafe act, further distorting the assessment of accident causation.

Arndt (NIOSH, 1982) notes that there has been little supporting research published for Heinrich's theory of accident causation, while at the same time acknowledging its widespread use. He reports a study of 1000 punch press injuries in Wisconsin where it was clear that Heinrich's theory produced an unsatisfactory assessment of injury causation. In this study and others (API, 1981) it has been shown that unsafe acts which could not have been readily prevented by better equipment/system designs account for only approximately 25 percent of accident causation.

Perhaps we should not be surprised at the outcome of Heinrich's theory of accident causation since the accident sequence is primarily oriented toward the individual involved in the accident. Because it does not require an evaluation of the overall system in which the event transpired, it would be expected that the approach would most often find the person at fault. Unfortunately, as illustrated in a later section, this catchall category of human error has greatly restricted advances in accident research and vastly distorted responsibility and liability for accidents in many organizational systems as well as in the minds of their members. (NIOSH, 1982, pp. 13-17, 75-89).

The difficulties in applying Heinrich's one dimensional approach to accident causation have been recognized by other researchers such as Manuele (1982), Adams (1976), Shealy (1979), Peterson (1971) and is corrected in the latest revision of Heinrich's work by Peterson and Roos (1980). If human error (unsafe acts) is accepted as the major cause of accidents, then the only acceptable strategies for accident reduction with this approach are to select human operators who are less likely to commit human errors or to train persons to the point where they will not make mistakes. The selection of better workers for specific tasks is a nebulous undertaking where "trial by fire" elicits after the fact selection of the survivors. Thus, training has been the primary method employed in an effort to reduce occupational accidents. Yet training in itself has not proved to be the expected panacea for elimination of human error and the domino effect. Nevertheless, many safety professionals still firmly believe it to be the only intervention strategy which they can apply short of total automation of work tasks to reduce the incidence rise of accidents.

GENERAL MODELS OF ACCIDENT CAUSATION

Some of the philosophical as well as practical problems of developing an acceptable approach to accident causation have been presented in previous sections of this paper. It is appropriate at this point to consider the various models which have been developed to explain accident causation and also the advantages and disadvantages of using each model. The classification of models presented by Peterson and Roos in their revision of Heinrich's original text will generally be followed, with modifications made as necessary to permit a more complete presentation (Heinrich, Petersen and Roos, 1980).

Management Models

Bird (1974) revised Heinrich's domino theory to emphasize management's responsibility for accident causation. His revised domino theory is as follows:

(1) Injuries are caused by accidents.

(2) For each accident there are immediate causes which are symptomatic of problems in the overall system.

(3) There are basic causes in the overall management of the system which produce the immediate causes of the accident.

(4) The lack of management control permits the basic causes of accidents to exist in the system.

Bird (1974) further states that the loss control function of management consists of the following steps:

(1) Identification of the work activities necessary to reduce losses (this step encompasses the usual safety program functions of accident investigation, facility inspection, job analysis, supervisory training, design engineering, etc.)

(2) Setting of standards for measuring management performance.

(3) Measuring management performance in achieving established standards.

(4) Correcting unsatisfactory performance by improving the existing work activities.

Bird's (1974) approach therefore shifts the emphasis from the worker as the cause of injuries to the management system in which the worker exists. Recalling the earlier discussion of the process model suggested by Singleton (1983), it can be seen that there is a definite similarity to Bird's (1974) four steps. The question of specific causation for individual accidents is therefore left open in the process model.

Weaver (1971) added the concept of "Operational error" to the domino theory, producing the following questions related to the unsafe act or condition.

(1) Why was the unsafe act and/or condition permitted by management?

(2) Did the supervisor have enough knowledge to prevent the accident?

Zabetakis (1975) of the Mine Safety and Health Administration academy added the concept of accident causation as an unplanned release or flow of energy, again following the approach of the domino theory. Energy release is considered in the general sense, i.e. mechanical, electrical, chemical, thermal or ionizing radiation. Since unwanted energy flow is a fundamental source of accidents, a system may be evaluated and improved by studying:

(A) The sources of energy existing in a system.

(B) The means available to reduce the energy levels.

(C) The means of controlling the flow of the energy.

(D) The methods available for absorbing the energy should loss of control or improper flow occur.

The next major outgrowth of the domino theory is a causation model which is based on multiple factors that combine in a random manner to produce accidents/injuries. Thus, such models focus not only on unsafe acts of the injured person, but also on unsafe acts of fellow workers as well as the unsafe conditions which existed at the same time as the unsafe act. Attention is ultimately drawn to failures in the management system which permitted the multiple causal factors to come together at the same moment in time and produce the injury.

One of the best known management oriented approached to accident causation is called the Management Oversight and Risk Tree (MORT). It was developed by Johnson (1973) for use in the analysis of complex systems related to atomic energy. It could also be called a systems model such as those discussed in a later section.

MORT employs a very large schematic diagram of an accident etiology decision tree model to trace inductively events of an accident backward in time, to identify the sequence of unwanted energy flow, and to evaluate the adequacy of barriers to unwanted energy transfer to persons or equipment. Along the route, hazards arising from the specific accident circumstances, from risks acknowledged and assumed by management, and from general management systems and policy weaknesses which are potentially germane to a significant number of accidents, are identified. Thus, the MORT chart (which is much too large for reproduction here) is a disciplined method for determining a multiplicity of accident factors and is useful as:

(1) A checklist for ensuring that all of an investigators questions have been answered.

(2) A plan for suggesting follow-up and further probing.

(3) An analytical technique for understanding accident event relationships and sequences.

MORT is more useful, however, as a tool for evaluating a specific establishment's safety management program. A sampling of MORT-charted accident investigations can be used to identify management oversights, omissions and errors. Working through the diagram backwards from the general to the specific, MORT may be utilized as a blueprint for optimal allocation of resources in the building of a safety program defining all essential components.

Still several difficulties exist in adopting MORT to general accident investigation and application to most industrial workplaces. MORT is an analytical tool and is not an accident investigation procedure. Although a manual which assists in charting data is available, no techniques or guidelines for data collection are suggested. MORT is not an objective system. It requires extensive value judgments as to the adequacy or inadequacy of various conditions. In order to make such judgments, the generation of a multitude of criteria is required. MORT data from more than one establishment are usually not suitable for comparison. The subjective evaluation criteria with respect to adequacy varies between industries, establishments, and evaluators. MORT provides no method for encoding and retrieval of analyzed information; thus, there is no accident information data base to evaluate.

Although the concept of management error is a valuable primary contribution of MORT, the problems and conditions which are identified are of a general nature. They are not specific or unique to particular accident circumstances. Consequently, it is not practical, nor necessarily useful, to perform an organizational/safety analysis when investigating recurring accidents. Finally MORT is quite complex for routine use at the workplace. The system is directed towards investigation of only serious accidents, including potential disaster situations, such as nuclear power plant accidents. It is an excellent approach for its domain of application but of marginal utility in its present form to explain occupational injuries.

The foregoing examples illustrate the general concepts of the management-related causal models. There are additional management-related causal models which are similar that will be omitted because of space limitations.

Behavioral Models

The underlying concept of the first behavioral models was that of "accident proneness" of individuals. Thus, if one could identify which workers were "accident prone" and deal with them, injuries would be prevented. Some of the early researchers concluded that certain ethnic groups were "accident prone," or that some individuals were predisposed to "accident proneness." We would like to think that such concepts are now outdated in light of our present knowledge, but this is unfortunately not the case. A survey by the Bureau of National Affairs (1977) showed that 65 percent of the businesses surveyed regarding their safety program attempted to identify "accident prone" individuals.

In an attempt to expand the idea of "accident proneness," some researchers have attempted to quantify various life stressors in terms of a given number of points and then relate an overall point score to the likelihood of the individual having an accident (Alkov, 1972). The concept of this approach is that major events such as divorce, death of a family member, financial problems, etc. can distract the individual's attention from the task and produce the errors which lead to accidents and injuries.

Other behavioral models have considered motivational factors, the rewards of working safely, and the level of satisfaction received from the rewards of working safely (Petersen, 1975). It has been observed that many workers perceive little positive reward for working safely, resulting in a negative or punishment-oriented reward structure derived from the injuries and/or disciplinary actions which result from an accident.

Epidemiological Models

Epidemiology has been described as the search for causal association between diseases or other biologic processes and specific environmental experiences or exposures. This model was originally developed for the study of diseases in human populations. The terms host, agent and enviornment were used to describe the part each played in the disease process. Similarly, the epidemiological model applied to safety research seeks to explain the occurrence of accidents/injuries within the system of host (injured victim) agent (means of injury) and the environment (physical, psychological and social factors related to the accident). Statistical methods are frequently employed to derive a common set of factors surrounding an accident, and thus infer cause of the accident. Gordon (1964) and McFarland (1965) were two early proponents of an epidemiological approach to injury causation. Haddon (1964) was successful in implementing an epidemiological approach to injury causation in transportation accidents while he was director of the National Highway Traffic Safety Administration (NHTSA).

This method requires that far more parameters of the host and environment and their interactions be ascertained and studied than had been considered in earlier models. This approach with its expanded requirements, recognizing the interactive nature of the accident process, is a significant advance over previous methods. In fact, it has provided a framework for applications of many systems approaches which incorporate human operator variables, environmental factors and task demands. The National Institute for Occupational Safety and Health (NIOSH) now has a major study underway to explore the usefulness of this approach in the study of accident causation. The study is being administered under the supervision of the Division of Safety Research located in Morgantown, West Virginia. It is hoped that this study will demonstrate the usefulness of this type of model for occupational injury research.

Systems Models

The emergence of systems engineering as a discipline in the 60's gave rise to many new applications of systems theory, including systems safety. Various systems safety models have been developed which will be discussed briefly.

Failure Mode and Effects Analysis

This is a system developed by reliability engineers, where components, assemblies and subsystems are analyzed for potential failure points and their possible effects on the overall system objectives. This approach is almost entirely concerned with system hardware and assessing probabilities for mechanical failures, with little attention being paid to possible human errors. Another shortcoming of this approach is that many of the failure points suggested have nothing to do with possible accident situations; thus protection of human operators is not fundamental.

Criticality Analysis

Similar to failure mode and effects analysis, this approach ranks items in any system to determine which items should be given more intensive study for a hazard elimination. Special requirements for redundancy, reliability improvement, or quality assurance are noted as complex mathematical probabilities are calculated for hardware failures. Fail safe hardware designs are then applied at these critical points; yet, because of the broad variety of components that can be considered critical, no system can be made error free without massive redundancy requirements.

Interface Analysis

This approach details the physical and functional relationships of subsystems in an effort to avoid design incompatibilities between units that might allow for potential accident situations. The analysis establishes not only that separate units can be integrated into a viable system but also that the normal operation of one will not impair the safety or performance of others. Still, the number of interfaces between units can be staggering when one considers all physical clearances and compatibilities, variations in energy output levels of subsystems, and other effects on whole systems when sub units may go astray.

Fault Tree Analysis

This systems model is based on constructing a logic "tree" of events which can lead to an undesirable system outcome, i.e. injury to an operator of the system. The analyst focuses first on component failures (hardware or human errors) and thinks deductively about what could cause them. He then thinks inductively about their effect on the safety of the system. The logic "tree" is graphically presented to aid in analyzing the process. Computer programs are necessary for the evaluation of analyses beyond the elementary level.

The systems safety models have been applied most extensively in military and aerospace endeavors where the focus was on potential failure points in the system hardware. Little quantitative data exists on human error rates, thus frequently precluding inclusion of the human component in such analysis. Since the objective is usually to predict likely points of system failure, injury to the people in the system is only an indirect output of such analyses. Some progress is being made to apply systems safety techniques to the typical occupational environment, but at present there is not a suitable global approach which is cost effective.

Human Factors/Ergonomics Models

In describing the Heinrich (1959) model of accident causation earlier, it will be recalled that he attributed approximately 90 percent of accident causation in a sample of accidents to unsafe acts. In the discussion of systems safety models it was noted that human error or "failure" rates could be incorporated in some models along with hardware failure rates to predict the probability of successfully completing the mission of the system. However, it also was noted that insufficient quantative data exists to predict human error rates in many of these systems. The accident causation models developed by Human factors engineers or ergonomists attempt to provide insights into the problems of "unsafe acts" or human error rates which are lacking in other accident causation models. Because of the importance of ergonomics causation models in improving occupational safety, a brief background of the discipline is presented before discussing the causation model.

The term ergonomics was coined in the United Kingdom after World War II when a name was needed to describe a new discipline. It is derived from two Greek words, one being ergo, meaning work and the other being nomos, meaning laws. Ergonomics is therefore the science devoted to understanding the laws or principles which govern the design of work systems. A professional society known as the Ergonomics Research Society was formed by the practioners of this new discipline who called themselves ergonomists. An organization with similar aims was founded in the U. S. in 1957 and called the Human Factors Society. The work of the founding members was termed "human factors engineering", or engineering psychology. Whether they are called human factors engineers or ergonomists, the scientists who practice this discipline draw on a number of basic science disciplines in order to have the necessary information for designing work systems. These disciplines include medicine, physiology, psychology, sociology, engineering and physics. Ergonomists are concerned with worker safety, effectiveness and efficiency (attaining the objectives at a reasonable cost) where people are a part of the system.

A paper prepared by Singleton (1982) for the World Health Organization, outlines the eight major issues which are addressed in the study of ergonomics. These issues are:

Human/Machine Interactions - This area of ergonomics is concerned with an analysis of the functions which can best be performed by a machine and the functions which can best be performed by humans in accomplishing a given system function, and the interactions which must take place between humans and machines in the process. The analysis must focus on how the man obtains the information which is necessary to operate the machine, how the information is processed, given the background and training of the operator to reach a decision regarding the appropriate way to control the machine, and then the action which is taken by the man or woman in controlling the machine so that the operation is safe and it meets the necessary production criteria. This process has been schematically presented by McCormick (1976) as shown below.

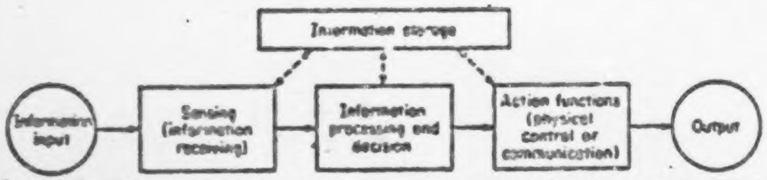
Information storage
Information input
Sensing (information receiving)
Information processing and decision
Action functions (physical control or communication)
Output

Figure 1: Types of basic functions performed by man or machine components of man-machine systems.

The process will be described using an automobile as an example, since most people are familiar with it as compared to a complex machine in a factory. Information input comes from both outside and inside the vehicle and consists of direct sensing and indirect sensing. Direct sensing consists of viewing the other vehicles on the roadway, the course of the roadway, traffic control signals, etc. and hearing warning sirens of emergency vehicles, the sound of a defective muffler, etc. We also sense some things by feel, such as the steering resistance or "feel", of the road, lateral acceleration of our vehicle when turning, etc.

Other information is sensed indirectly through visual displays on the dashboard such as speed, engine functions, symbols or labels on various controls such as lights, heater, windshield wipers, etc.

Sensing information requires that it be within our visual auditory (hearing) and tactile (touch) capabilities. The meaning given to information sensed, i.e. engine temperature indicator, depends on our prior training and experience which is represented as information storage in the schematic.

After sensing information, i.e. engine temperature indicator glowing red, we must process the information and make a decision. This step again depends on our prior training and experience as well as any unusual stress at the moment. If we are driving someone to the hospital, we may not stop to have the radiator checked as we usually would.

Once a decision has been reached, it must be implemented by taking some control action or communicating with someone else in the system. Taking control action means the proper control must first be identified (often a problem in the work environment), the proper method to operate the control must be understood, the control must be within reach and sufficient strength must be available to operate the control. We have probably had the experience of trying to find the switch for the headlights and turning them on when driving a rental car. Workers in the occupational environment must deal with a large variety of machines whereas we were only switching from one make of auto to another. Even the most elementary application of a simple model such as this to the analysis of many human/machine systems would have demonstrated that serious deficiencies existed in one or more of the functional areas as shown in the schematic and in turn would have prevented a serious accident leading to personal injury. Unfortunately, as noted earlier, many accidents have simply been tabulated as being caused by "human error", and therefore the same accidents will be repeated in the future until a better analysis is performed to understand what has occurred in the breakdown at the human/machine interface.

Information Conditions - It is essential that the worker receive proper information regarding how to do the task in a safe and effective manner. Feedback must be given the worker to correct any deficiencies in the way the task is being performed. This area of concern is generally related to the training and education which a worker receives regarding the way to perform a task. It is essential that safety and health information be integrated in the overall pattern of instruction so that the worker understands how to perform the task safely when the training program is accomplished. As conditions change in the workplace the training must be reviewed and updated.

Environmental Conditions - The consequences of adverse environmental conditions are often insufficiently considered in the design of work tasks. Environmental stressors such as heat, noise and vibration can affect the workers' health and safety directly as well as being an indirect source of distraction or obstruction in the necessary information transfer or recall and thus lead to a serious accident. In addition, the worker needs a sufficient amount of lighting of the correct type in order to work in a safe and productive manner. The amount and type of lighting must be established using ergonomic guidelines.

Application of Forces - There are efficient and safe ways of exerting the necessary muscular force to perform a task. Unfortunately, there are also many inefficient and frequently unsafe ways of exerting muscular force in the performance of a task. The worker must be selected using strength tests related to the task demands and trained properly in order to avoid the overexertion type of injuries. This type of injury accounts for the largest proportion of worker compensation claims among all of the causes of injury in the workplace. The most important overexertion injury involves the lower back, accounting for one-fourth to one-third of all worker compensation claims (NIOSH, 1981).

Posture - Many workers are forced to assume very tiring and unfavorable postures for performing their work tasks. The build-up of such fatigue is often a contributing factor to an accident. The cause of such accidents is often categorized as apparent lack of attention on the part of the worker, when in reality the worker was too fatigued to focus on performing the task safely.

Temporal Conditions - It is important to understand the relationships which exist between safety and productivity and such variables as the length and distribution of the working time, including rest pauses, and the way in which shift work is organized.

Social Conditions - It is important to understand the way in which workers view the rewards of their work, especially the positive and negative aspects of working safely and productively as noted earlier when the behavioral models were discussed. Some workers, apparently in order to impress their fellow workers, will attempt to project a macho image in the acceptance of unnecessary risk. It is clear that such behavior must be readily recognized and dealt with in these workers if serious accidents are to be avoided to that worker as well as his or her fellow workers.

Peer group or supervisory pressure will frequently exist to work in an unsafe manner to meet a production quota. The individual worker must be motivated to resist such pressures and rewarded (rather than punished or ostracized) when he or she refuses to work in an unsafe manner.

Energy - It is necessary for the worker to be adequately fed in order to posses the necessary energy to perform his or her work task. While less a problem in the U. S. as compared to some other countries of the world, it is important to encourage workers to adopt healthful diets which include sufficient quantities of the right foods.

The foregoing paragraphs have presented a brief overview of the ergonomic analysis and design process. Ergonomists usually subdivide the field into information and physical ergonomics for purposes of analysis and design. Information ergonomics is concerned with the collection, display, sensing and processing of information. Physical ergonomics is concerned with questions related to worker size, strength, motions capability and working posture.

In addition to the general ergonomics methodology described in the preceding paragraphs, some specialized techniques of analysis are also used which could be categorized as ergonomics-related causal models. These are described in the following paragraphs.

Link Analysis - This approach evaluates the transmission of information by type (visual, auditory, tactile), rate, load, and adequacy. A diagram is prepared which locates all human and hardware elements in a system and the communication links between the human and equipment are noted. The frequency of each link occurrence is determined and the importance of it is assigned a value. Elements are then arranged so that the links with highest use - importance values are closest to the operator.

Critical Incidence Technique - A common complaint in systems design is that old failings are often carried over into new designs. Thus, this approach seeks, primarily through personnel interviews, to find all points in previous similar systems where accidents almost occurred (near misses). In effect this technique accomplishes the same result as good accident investigation: identification through personal involvement of a hazard that could result in injury or damage. As noted earlier it has been estimated that for every major injury there are 300 near misses; therefore, the pooling of near miss data with that of actual mishaps vastly increases the population of data for analysis.

Task Analysis - Analysts generate sets of written procedures showing all sequential actions required of an operator to perform his job. These jobs may vary from conducting an operation repeatedly to support functions such as maintenance, repair, testing, handling and calibration. The task analysis for each is a review of all actions that must be performed, the equipment that is operated,and the environment in which the tasks are conducted. Several individuals then review and simulate these factors in an attempt to find potential problem areas and situations.

Contingency Analysis - A contingency is an emergency or a potential emergency situation arising from an unprogrammed event or action, unavoidable natural phenomenon, or human error. The severity of a contingency is a function of the magnitude or the affecting condition and the capacity of the system to withstand it, available system reaction time, and the capability of the operator to trace corrective action. The analysis must consider all of these factors and recommend all actions requisite to return the system to a safe condition or minimize resulting damage.

CRITIQUE OF ACCIDENT CAUSATION MODELS

A variety of models were presented in the preceding section which have been proposed to explain accident causation. These models will be critiqued in terms of their application to problems in the *occupational safety environment*.

The inherent simplicity of *Heinrich's domino theory* no doubt accounts for its widespread acceptance even today, especially among small and medium sized establishments. A minimum amount of training is required to understand its application, and it does provide an answer to the question of "cause", even if it is a superficial one. Since most accidents are classified as the result of "unsafe acts", it permits management to dismiss serious consideration of workplace safety by pointing the finger at the imperfect worker. Unfortunately, too much of American industry still finds this approach attractive for this reason.

The adaptations of Heinrich's theory which place the responsibility for unsafe acts *and* unsafe conditions on the *management system* of the enterprise represent a major step forward in preventing occupational injuries. The motivation at least exists to improve workplace safety, even if the causal explanations are too simplistic. Most accident investigation and reporting systems today follow this concept. The result is a limited ability to predict the occurrence of hazards in the workplace and develop effective countermeasures.

Behavioral Models have contributed to our understanding of the human component in accident causation, although some approaches based on studying "accident proneness" have contributed little or no useful information for prevention. It is unfortunate, as noted earlier, that many firms still expend resources in trying to identify "accident prone" individuals, rather than considering the larger problem of accident causation.

The "chain-of-events" or multiple events models recognize that many factors can influence accident causation and thus represent progress in comparison to single event models. However, none of these models have a sufficiently simple organizing structure to make them useful across a wide range of industry. The principal organizing structures proposed involve collecting information about temporal or sequential relationships between multiple events. Although this information is useful in explaining accident causation, it is often difficult to collect and other relationships are not recorded.

The epidemiological model has value in its organizing framework of host, agent and environment, and places emphasis on the need for a multidisciplinary approach to accident causation. Some critics say that accident occurrences do not behave like disease epidemics and therefore the model will not adequately explain why accidents happen or how corrective measures can be identified. As noted earlier, the NIOSH research currently being completed should help to answer this question.

An adaptation of the epidemiological model was applied successfully to the area of transportation safety as noted earlier. Application of the model would be difficult for much of industry at the present time because of the level of expertire required.

The *systems models* have been developed primarily to evaluate system, subsystem and component failure modes, progressing either upward or downward in a hierarchial arrangement of system components. The primary focus has been on non-human or hardware failures. Although the potential exists for incorporating human error rates in these analyses, little quantative data is available. The more progressive industrial firms often follow some form of FMEA analysis on a prospective basis to uncover potential failures in plant and equipment designs.

The *human factors/ergonomics models* focus on the human/machine interface and thus provide a much needed emphasis on the joint interaction of human and machine in achieving a safe working environment. Since the thrust of ergonomics practice is to *design* the work task, (as compared to installing the machine and letting the worker try to adapt) safety is an integral part of the job design and human error rates are evaluated in terms of their impact on worker safety. This phase may require further research studies if sufficient quantative data is not available for the evaluation. The principal shortcoming of the ergonomics model is the absence of any analysis of hardware failures beyond the human/machine interface. However, such failures are rare in relation to those that occur in the design of the human/machine interface.

In summary, no single model provides a wholly satisfactory approach to explaining the various facets of accident causation. It is clear that a satisfactory explanation of why accidents/injuries occur must go beyond a simple cause and effect model, since many factors are involved whose relationships are often difficult to adequately evaluate. At the present time it is suggested that the epidemiological model is useful for identifying major categories of causal factors in the workplace, and that these major categories can in turn be studied in-depth using the ergonomics model discussed.

APPLICATION OF CAUSAL THEORIES

It is instructive to consider a single occupational accident and apply the various causal theories to the investigation of this accident to understand how they differ in approach. A description of the circumstances as found by the author when called to investigate this accident is given first, followed by a brief discussion of the outcome if a particular causal theory is applied.

Description of Accident

The worker was painting the inside of a large industrial plant under construction. He was using a large mobile work platform sometimes called a "cherry picker". A sketch of the work platform is shown below.

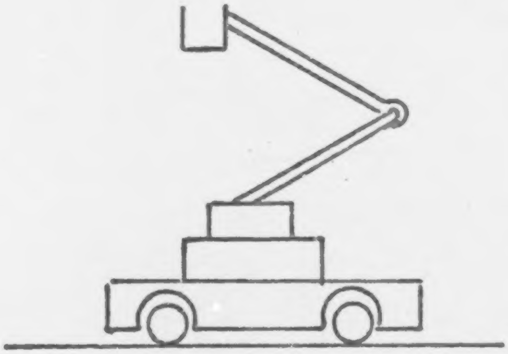

Figure 2: Sketch of Mobile Work Platform

The worker platform, sometimes called the "bucket" is shown in the sketch below, along with a close-up view of the controls which the painter was using to position the work platform as he painted the large beams in the ceiling. The beams are called I-beams because their cross sectional shape resembles the capital I. The painter did not use the equipment regularly, having had only a few hours experience with it before his accident. The painter was found with a severe head injury adjacent to an I-beam with which he had apparently collided.

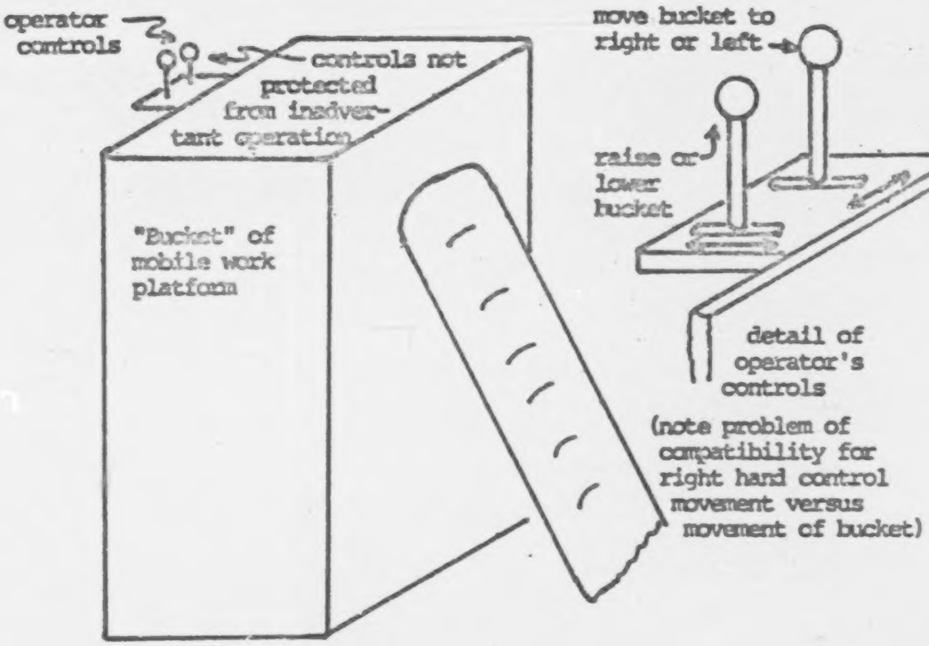
operator controls
controls not protected from inadvertant operation
"Bucket" of mobile work platform
move bucket to right or left
raise or lower bucket
detail of operator's controls
(note problem of compatibility for right hand control movement versus movement of bucket)

Figure 3: Sketch of "Bucket" and Controls

Using Heinrich's approach to causation, the injury would have been reported as resulting from an unsafe act, i.e. the painter operated the controls in such a manner as to produce his collision with the I-beam. (In fact, this was the classification used when the injury was reported under the workers compensation system).

The management models would have directed the investigator's attention to management failures that permitted the accident to happen. Some typical questions would be as follows:

(1) Was the painter experienced in using the equipment?

(2) Should head protection (hard hat) have been required?

(3) What type of training was given by the supervisor in using the equipment?

(4) Did the lift controls malfunction?

(5) Was the equipment properly maintained?

In this instance it was found that the painter had little experience in using the equipment and was given only minimal instruction in its use. Wearing a hard hat was not required because of the difficulty of wearing one over the respirator which was required while spray painting. No apparent problems existed in the maintenance of the equipment.

The behavioral models would suggest that the following questions be asked:

(1) Was the painter "accident prone"? (had he been involved in other accidents?)

(2) Were there unusual stresses as a result of major life changes?

(3) Was the painter generally satisfied with his work?

(4) Were the relationships with his boss and fellow workers satisfactory?

In this instance the painter had an average frequency of accidents on his work record. No problems of an unusual nature were apparent in his life when interviewing to his family.

The *epidemiological model* would have directed the investigator to search for other similar accidents to comprise a population for study. If such a pool of similar accidents were available for study, then the approach would be to determine what factors seem to be common in each accident.

In this instance it was difficult to establish a pool of accidents for which much useful information was available. After some searching in the area of product liability lawsuits, it was found that four lawsuits had been filed for this type of equipment where similar accidents had occurred with no apparent malfunctioning of the equipment.

Using the *systems models*, the investigator would focus on the components, subassemblies and assemblies which make up the overall lift, analyzing failure modes and effects and/or constructing a fault-tree diagram. The primary focus of the analysis would be on the electro-hydraulic control system for the lift, attempting to learn if some transient or intermittent control problem had occurred, since the lift controls operated normally after the accident.

Using the *ergonomics model*, the investigator would focus on the following questions:

(1) Training and experience of the painter in using the lift.

(2) Physical size, limitations in upper limb movement, and strength of the the upper limbs.

(3) Placement of the operating controls, their labeling for method of operation and protection against inadvertent

operation.

(4) The compatibility between method of control operation or movement direction and movement of the lift.

(5) The strength needed to operate the controls.

In this instance, it was found that the worker appeared to have no problems of upper limb movement or strength, but had limited experience and training in using the lift. No protection was available against inadvertent control operation (a wire mesh cage over the upper perimeter of the two control levers would have prevented inadvertent operation). A major problem of control movement vs. lift movement compatibility was found for the lever controlling rotary movement of the "bucket" about the machine base. Pushing the lever forward away from the body caused the "bucket" to rotate counterclockwise, while pulling it toward the body caused the "bucket" to move clockwise as shown earlier in the sketch of the controls.

The ergonomist would therefore have concluded that two possible causes existed for the accident.

(1) Since the controls were not protected from inadvertent operation, one of the hoses of the spray painting system had become entangled with the control for rotary movement and had caused the painter's head to collide with the I-beam edge before he was aware of the problem, or,

(2) Since the painter was inexperienced in using the equipment and there was a control movement vs. lift movement compatibility problem, he could have operated the control in the wrong direction and thrown himself into the edge of the I-beam.

Using a multiple events model, and the information provided in discussing the preceding approaches, one could construct a causal explanation as follows:

(1) The painter was inexperienced, and

(2) The controls were unprotected from inadvertent operation, and

(3) The paint hoses became entangled in the controls.

Another approach might be as follows:

(1) The painter was inexperienced, and

(2) A control compatibility problem existed, and

(3) The labels to indicate method of control operation were partially obscured by the overspray from the painting operation (which was found to be the case).

In summary, a number of observations can be drawn from this example regarding the causal models:

(1) The model which appears to provide more useful information for prevention is the ergonomics model. However, it is desirable to apply one of the systems models to uncover any potential hardware problems which may have caused a transient control problem, even though the controls appeared to function normally after the accident.

(2) Even though some of the models would focus on more training as a prevention strategy, it would appear to have less potential value than control shielding and redesign.

(3) Unfortunately, a large proportion of industry today would not have the expertise to apply any of the models except the one of Heinrich.

SAFETY CONTROL TECHNOLOGIES

Control Limits

In order to understand the difficulties which are often faced in the area of safety control technology, it is helpful to draw a parallel between the methodology used in the control of health hazards by industrial hygienists and the methodology used by safety engineers for preventing traumatic injuries in the work place. The methodology of industrial hygiene (recognition, evaluation and control of workplace hazards) generally involves the epidemiological analysis of a given pattern of occupational illness, with the results of the analysis being stated in terms of an assessment of the risk of the occupational illness as a function of the exposure level to the toxic material in the workplace. In some instances, only one study at a given exposure level is available to relate to the excess incidence of a given occupational disease, while in other instances two or more levels of exposure may have been studied which can be used to predict some function of exposure level in relation to the excess occurrence of a given occupational disease.

The next step in dealing with an occupational illness is to determine a permissible exposure level (PEL), i.e. one that will prevent occupational illness and then to use control methods for keeping worker exposure below the PEL. The problem usually becomes one for process engineers to develop a system to contain the emissions of the toxic material within the exposure control limits. The less desirable alternative is to require the worker to wear personal protective equipment to prevent exposure to the toxic material in the workplace.

If the approach taken for occupational illnesses is compared with the approach taken for occupational injuries, it becomes apparent that some serious difficulties arise in establishing acceptable control levels for the physical agents which produce injuries to the worker. Because of the many problems enumerated earlier regarding the collection of information regarding the causes of occupational injuries, it is seldom possible to describe a functional relationship between a given exposure level of a particular physical hazard and the resulting incidence of injury to the worker. Research employing a form of injury epidemiology has been carried out in the past through the expenditure of significant amounts of money in the area of transportation safety. The pattern and severity of injuries as a result of automobile crashes has been related to vehicle design aspects, vehicle speeds, and features of the roadway. While the information data base which has been assembled over many years of data collection is not as complete as might be desired, it is certainly a much more comprehensive data base for the types of injuries studied than any comparable data base for occupational injuries. (Haddon, 1964)

In the absence of the necessary quantitative data to define acceptable control technologies for safety hazards, a great many safety standards have been based primarily on logic and/or intuition. For instance, it is possible to argue logically that any injury resulting the amputation of a worker's hand or fingers in a punch press is unacceptable and therefore a control technology must be employed which can prevent the occurrence of any amputations. On the other hand, if one considers the problem of injuries produced from falling, the use of logic and/or intuition does not lead to clear-cut requirements for an acceptable control technology. In the most comprehensive study of injuries resulting from falls ever conducted (Snyder, 1977), it was shown that the severity of injury was related to the height a person fell and the surface on which the person fell, which varied greatly from one accident to the next. Because of this ambiguity in the data, it is difficult to set effective, enforceable standards for preventing falls in industry, especially the construction industry. A number of falling hazards still exist for which some construction contractors believe no suitable cost-effective technology for eliminating the hazard has been developed to date.

In attempting to address the overall question of safety control technologies, one finds many instances where the relationship between the probability of injury and the use of a given control technology is not adequately documented. Because of this absence of documentation, employers may be reluctant to invest in a given control technology and workers may be reluctant to use the safety devices provided because they are not convinced of the effectiveness of the technology in preventing injuries, or it interferes with their work pace and supervisors fail to change the pace of the job. Basic measures of exposure are often quite difficult to obtain for many types of occupational injuries. What is needed is a reasonably good estimate of the levels of forces which produce a given type of injury to the body and an assessment of an acceptable control level for these forces. Further, it is necessary that some information be available regarding the probability that workers will be exposed to a given level of these forces during a period of working time. With such information, safety engineers and machine designers can then develop and follow standards of design for equipment and systems which will assure that worker exposure to forces above a given level are controlled. Such standards could be supported by regulatory agencies, the courts and should be acceptable to employers and workers.

With this background, some of the major approaches to safety control technologies will now be presented.

Classical Approach to Safety Engineering

If one reviews the table of contents for a classical safety engineering text, the following topics are usually addressed in the text:

1. Machine guarding.
2. Fire and explosion protection.
3. Prevention of falling injuries.
4. Structural safety in building design.
5. Prevention of electrical shock.
6. Safe use of hand tools (powered and non-powered).
7. Safe design of boilers and pressure vessels.
8. Safety in handling and transporting materials.
9. Safety rules for working with dangerous substances or ionizing radiation.
10. Protection against the effects of noise and vibration.

(See for instance the Model Code of Safety Regulations for Industrial Establishments, published by the ILO, Geneva, 1954).

The application of these safety engineering principles has been more successful in some areas than others. In general, significant progress has been made in reducing the injuries associated with areas (1), (2), (4), (5) and (7) listed above. A more in-depth discussion of these areas of injury prevention is presented in conjunction with the treatment of major safety technologies which follow later in this paper. Progress in reducing injuries in the remaining areas has not been as significant, and even where progress has been made, there is a need for new approaches to bring about further injury reduction.

With the possible exceptions of fire prevention and safe design of boilers and pressure vessels, an overall systems approach has not been taken in the safe design of equipment and workplaces in industry. There are many reasons why this has not been done. Some of the more important ones are as follows:

1. Lack of training in safety and health principles for engineers, architects and industrial designers.

2. Lack of a suitable methodology for assuring systems safety in engineering design.

3. Cost of Collecting the necessary safety data, analyzing the data and utilizing it in systems design.

Major Safety Technologies

Technologies for preventing workers from being caught in or between moving parts of machines. The technologies for dealing with these types of injuries are well developed in the U.S. today and if they were carefully followed in all workplaces, many injuries could be prevented. Guards such as those shown in Figure 4 which consist of physical barriers to prevent the worker's body members from being drawn into machines have been successfully employed for many decades, and yet many machines still exist without adequate guarding. Because many of the guards must be used at the point of operation of the machine such as a punch press, they frequently reduce the productivity of the machine and the temptation therefore exists to make the guards ineffective in order to increase productivity. Newer technologies are currently being developed wherein a guard based on the use of a series of light beams is used rather than an actual physical barrier. The principle of these guards is that any interruption of the light beams results in the machine operation being interrupted until the person removes the part of the body interfering with the transmission of the light beams and then the machine will perform its functions. Unfortunately, these devices have not yet received wide application because some questions still remain of their reliability. It is absolutely essential that such a device which is relied on by the worker to provide protection be fail-safe in its operation.

Another major category of machine guarding problems exist during the time when machines must be maintained. In many instances, the worker is tempted to try to perform maintenance on the machine while it is still operating and thus exposes himself to a high probability of injury. The technology now exists for applying an electrical or mechanical interlock to the guards that are present on a well-designed machine so that any time the worker is tempted to remove the guard and perform maintenance on the machine, the machine is automatically stopped. Broader application of this technology would no doubt reduce a number of injuries which occur unnecessarily during the maintenance of many machines.

Injuries which occur as a result of falling, either on the same level where the worker is walking or from a height. As noted earlier, this type of injury is difficult to prevent in many types of activities, particularly in the construction industry. The National Safety Council states that 20 percent of compensable work injuries result from falls.

The technological challenge exists in developing a suitable restraint system to prevent the worker from falling while at the same time not interfering significantly with the work task being performed. Erection of the steel structure for many buildings presents an example of this type of problem. Utilization of the technology presently available would no doubt prevent many falling injuries, but further technological development is definitely needed to provide more acceptable safety nets, safety harnesses, safety lines and lanyards, as well as improvements in the design of buildings and construction techniques. A number of important questions still remain in the technology for providing suitable barriers at the perimeter of buildings under construction which will prevent the workers from falling, as well as the design and installation of safety nets where other types of restraints for the workers cannot be applied.

Chaffin (NIOSH, 1982) has discussed some of the research needs related to improving the technology of fall protection, estimating that at least 3.5 million dollars would be required to adequately fund the necessary research.

Injuries to the head. Significant advances have been made in recent years in the design of head gear to protect the head from injury due to falling objects or due to contact with rigid objects in the work place. Unfortunately, many workers still find the types of head protection available to be unacceptable and therefore refuse to use the head gear which the employer provides. Significant advances have been made in the application of high-strength plastic materials such as polycarbonates for the protection of the eyes. Very light weight and strong goggles and safety glasses now exist to prevent eye injuries when employed by the worker.

Injuries to the feet. The technology currently exists for preventing a large proportion of the injuries to the feet which result from heavy objects falling on the feet or from puncture wounds when sharp objects puncture the sole of the shoe. With the possible exception of fitting some types of footwear for the increasing number of women workers, adequate footware is available to prevent most foot injuries. Many employers now pay all or a substantial proportion of the cost of safety footware for the their workers.

It can be seen that a number of the areas of safety technology discussed above are related to the general category of personal protective equipment. In general, the safety equipment industry, other than fire protection, has been dominated by a concern for developing and marketing fire protection and personal protective equipment. Thus, when one speaks of safety control technologies over the past fifty years in the U.S., the two major areas which come to mind are fire protection and the development of personal protective equipment.

Injuries resulting from fires and explosions. The control technology industry for fire protection has achieved some very important successes in the past two or three decades. The incidence of workers being burned as a result of fires in their workplaces has been reduced in many industries through the application of sophisticated fire control technologies such as water deluge systems, carbon dioxide extinguishing systems and other new techniques, coupled with significantly improved fire detection and early warning systems. (OSHA Rulemaking Record, 29 CFR, Part 1910, Subpart L). A notable exception to this general trend of improvement has been the grain elevator industry. The frequency of major fires and explosions in this industry has resulted in a combined effort by OSHA, NIOSH and the National Academy of Sciences to produce a substantive analysis of the problem and suggested measures for reducing the injuries resulting from such accidents in the future. (National Academy of Science, 1981). While some improvements in safety control technology have definitely been implemented in recent years when elevators which had been destroyed were rebuilt, there still exists a need for improved technology which can be applied to the retrofitting of many rural grain elevators throughout the U.S. which remain as high hazard operations.

Injuries resulting from overexertion. No single category of injuries has resulted in more workers compensation claims and cost to employers and workers than this type of injury, particularly injuries to the low back as noted earlier. In addition, there are an increasing number of incidents of chronic musculo-skeletal injuries in the work place which affect the upper limbs. The control technology for dealing with these injuries is beginning to develop, but progress has been slow over many years. It is expected that the publication by NIOSH, with the cooperation of OSHA, of a Work Practices Guide for Manual Lifting (NIOSH, 1981) will stimulate the development of suitable technologies for dealing with the problems of injuries resulting from manual materials handling, particularly injuries to the lower back. As noted in this work practices guide, the potential exists for saving literally billions of dollars in industry if a major reduction can be achieved in the incidence of low back injuries. In order to reduce low back injuries from manual materials handling, improvements must be made in such areas as the containers in which the product is handled, the conveyors which are used to move products, the design of parts handling and storage bins, and various types of lifting aids for the worker. Part of this control technology is based on strength testing of workers and then designing the task so that it does not require more strength than the worker can safety exert. This area presents an excellent example of the potential for applying ergonomic and biomechanical analysis to the problem in order to fully document the nature of the injury process and in turn to suggest ways in which the human/machine system can be designed to avoid such injuries.

THE ECONOMICS OF INJURY PREVENTION:

Decisions are often made in industry to apply a given control technology based on the economic costs involved, the benefits expected and the other non-economic values of the management. This section deals with the problem of assessing the economic costs of accidents and injuries and in turn the benefits of prevention.

In order to understand the economics of accident and injury prevention, it is necessary to define some of the terminology which is used. The usual approach is to consider that accident costs are comprised of direct cost and indirect cost (Hammer, 1981; Heinrich, et al, 1980 and Blake, 1953). Direct costs are considered to consist of worker compensation payments and medical expenses for the treatment of the injured party. It is clear that the employer will be able to determine the direct cost of medical treatment necessary as well as the direct cost of payments to the injured worker during the time the worker is absent from the job.

A second category of costs is associated with an injury producing accident which are labeled indirect costs. Hammer (1981) notes that the ratio of indirect cost to direct cost has been estimated by a number of researchers, ranging from a ratio of 1:1 to 20:1. The most frequently cited ratio is 4:1 for indirect costs to the direct costs of an accident. Some of the more commonly cited indirect costs of an accident are as follows:

1) The cost of lost time of the injured employee.

2) The cost of time lost by other employees who stop work because of curiosity, to assist the injured employee or for other reasons.

3) The cost of time lost by the foreman, supervisors, or other management personnel in order to assist the injured employee, investigate the cause of the accident, arrange for a substitute for the injured employee, training or otherwise instructing the new employee, preparing various types of reports related to the accident, providing information and/or testimony to investigators or attorneys, and appearances before courts, commissions or other investigating bodies.

4) Cost of first aid and other medical attention provided by the employer which is not usually paid by the insurance carrier.

5) Cost due to damage to machines, tools, supplies or other property.

6) Incidental costs related to failure to meet required production schedules or other similar commitments.

7) Cost to the employer for payments to employee pension or other benefit systems.

8) Cost to the employer in differential wage payments upon the return of the injured employee when the injured employee is no longer able to perform the task which he had performed before the injury.

9) Loss of overhead cost as well as profit associated with the production which would have been produced by the injured employee.

If the list of indirect costs given above is examined, it will be seen that the cost associated with many of the items are not normally collected as a part of the cost accounting system applied by an enterprise, and even when some of the costs are normally collected, the system may not be detailed enough to provide these costs as related to one or more specific accidents, but rather on an overall basis. In many instances supervisors may not even be aware of the medical or compensation costs associated with an accident because this information is usually collected and analyzed by the industrial relations department or the safety department in an enterprise. Because such costs are not visible to the managers of most enterprises, the inherent tendency is to underestimate the cost of accidents and injuries to an enterprise.

Hammer (1981) observed that when the Railway Safety Act was being considered in 1883, a railroad executive noted that it would cost less to bury a man killed in an accident than to put airbrakes on a railroad car. While a great deal of progress has been made in developing enlightened management approaches to safety in the workplace since this statement was made, it still unfortunately reflects the attitude of too many employers. There is therefore the tendency to trade lives for dollars of profit where the direct cost of injuring or killing an employee is less than the cost of providing the necessary protection. One of the most notorious instances of this type of thinking was observed by OSHA in a court case brought in the state of Virginia against a contractor for failing to adequately provide protection for an employee working in a deep trench which caved in on the employee resulting in his death. In this instance, the required payment by the state worker compensation system was not even adequate to provide for a minimal burial of the employee. The low worker compensation insurance premiums paid by the employer which in turn supported the very inadequate worker compensation system of the state therefore did not serve as a reasonable deterrent to the grossly unsafe practice of the employer.

It is necessary to note from the information provided in the preceding paragraphs that the economics of providing adequate protection for the employee in the workplace must be better understood by state legislatures, the U. S. Congress, and employers. There is a distinct tendency to focus on the cost of providing safe working conditions for the employee without in turn taking into account the indirect costs associated with accidents, and in many instances even the direct costs associated with an accident are not fully understood by those who are making the judgments regarding the design of these systems and equipment in the workplace.

Many estimates have been made of the total cost of accidents and injuries in the U. S. today, most notably those made by the National Safety Council. These estimates generally range in the order of fifty billion dollars or more each year. The spiraling costs of providing medical care in the U. S. have made the headlines many times over the past years. Unfortunately, the costs contributed by treatment of injuries in the workplace to these total medical costs have not been nearly as well understood by the U. S. public. The declining level of productivity in the U. S. manufacturing and service sectors has also made the headlines frequently in the past years. Again, the impact which industrial accidents and their associated losses have had on this declining productivity has not been nearly as well publicized.

PRINCIPLES FOR A SUCCESSFUL SAFETY AND HEALTH PROGRAM:

The ILO (1976) has presented the principles for an effective safety and health program in an enterprise. These principles have also been identified in studies by NIOSH (19) and by many other authors (Petersen, 1971, Hammer, 1981, NSC, 1980). They are briefly presented in the following paragraphs.

A definitive policy statement from top management requiring an effective safety and health program in the enterprise is the cornerstone on which any effective safety and health program must be based. The ILO suggests that such a policy statement might read as follows:

> "The officers of this Company believe that the safety of employees is of the greatest interest to the management, and ranks in importance with production, quality of products, and costs. While the maintenance of safe operating procedures in our plant can result in significant savings, we believe the human values involved are of much greater importance to both employer and the plant community. The acceptance and practice of fundamental safety principles by management and employees, with reduction of personal injuries to a minimum, will inject an element of team-play which will do much to foster a spirit of friendly cooperation throughout the Company."

The safety and health program of any enterprise should begin with a similar statement embodying the ideas presented in the policy statement above.

The next major ingredient of a successful safety and health program is the clear assignment of responsibility for the program to the various managerial levels of the enterprise. It is absolutely imperative that the safety and health program of an enterprise be viewed as the responsibility of each manager in the line management organization, rather than the responsibility of a staff safety officer or the safety organization. Organizations with successful safety and health programs have made it clear to the line managers that they have the full responsibility for the safe operation of the facilities and equipment under their direction. In addition to the responsibility for safety and health, there must be accountability on the part of line management for their safety and health performance. The safety and health performance of the line managers must be regularly evaluated and viewed with no less importance than their performance in achieving their goals for production levels, profitability or other such measures.

In order to provide the necessary support to the line organization which is responsible for safety, the enterprise should have available, either through direct appointment or consulting arrangements, the necessary staff to provide reliable information regarding appropriate safety and health practices for the enterprise. If the enterprise is small, then it may be necessary to obtain the expertise required in safety and health matters through the services of a consultant. If the enterprise is large enough to require the full-time services of a safety officer or safety staff, then this safety organization should be available to consult with the line organization regarding safety and health problems. It should also coordinate the overall safety program of the enterprise, and provide a variety of specialized services such as the collection and dissemination of statistics regarding safety and health performance, the promotion of safety and health through various forms of management leadership and employee awareness, and training in safety principles and practices for both employees and members of line management.

In many instances, it will be found helpful to organize a safety and health committee with representatives of the safety organization, workers and line management in order to coordinate and promote an overall program for the enterprise. Many useful references are available today regarding the organization of an effective safety and health program, including the *Accident Prevention Manual* of the National Safety Council (1980), Hammer (1981) and others.

INNOVATIONS AND TRENDS

Application of Systems Safety Methodology

The value of using one of the different systems safety approaches described earlier for improving the safety of products is a clearly emerging trend. This trend has been accelerated by the many product liability lawsuits filed in recent years. The manufacturers of products which could produce injuries are increasingly aware of their potentially large liability in producing products which are not as safe as the state of the art will permit. They are therefore willing to explore the use of systems safety approaches in an attempt to produce the safest product which is reasonably possible. This trend, coupled with the applications already made in space and military systems, could eventually lead to wider application in the work environment, given that the necessary economic incentives are present. As noted earlier, if manufacturers develop records which document the true overall costs of an accident or injury, then perhaps they will provide the necessary economic incentives.

Application of Ergonomics to Improve System Safety and Productivity

There is a very noticeable upward trend in the application of ergonomics to system design problems. Many companies now advertise the ergonomic merits of their product design (John Deere, Mercedes Benz, etc.), indicating an awareness that consumers are interested in this aspect of product design. Similarly, many firms are now applying ergonomic principles to workplace design in order to improve safety and performance and reduce fatigue. Of particular concern is the redeisgn of work methods and workplaces to reduce chronic musculoskeletal problems and overexertion injuries such as those to the lower back.

Improved Worker Training and Education Programs

One of the most important predictors of occupational injuries is experience on a particular job. Several studies in recent years have shown that 35 - 50 percent of the workers injured each year have less than one year of experience on the job. The author has studied one industry where 40 percent of the new workers were injured within the first six months on the job. Such studies point out the urgent need for improved training programs for young workers and workers starting new jobs. The New Directions Training Grants program of OSHA represnts one attempt to improve training of workers in safety and health. This Program provides funds to worker groups, employer or trade associations and universities to develop training programs for workers. Much more emphasis seems warranted by employers in the training of workers when they are initially assigned to a job.

NEEDS FOR FURTHER RESEARCH:

When one reviews the information which has been presented in the preceeding pages, it is clear that a significant amount of research needs to be completed in order to establish a sound basis for reducing the occupational injuries in industry today. To present a comprehensive list of all the various research needs is beyond the scope of this paper. A comprehensive research plan has been produced by the Division of Safety Research, NIOSH (1980). The following paragraphs outline some of the most urgent research needs.

Epidemiological Methods

It has been noted earlier in the comparison of methodologies used for research in the area of occupational health versus occupational safety that it is difficult to relate a given type of occupational exposure to the incidence of a given type of injury, i.e. there are often a number of different hazards, each of which is related to new or more causal factors. The study presently in progress by NIOSH will provide further insight into the applicability of epidemiological methods in trying to develop the necessary information to relate some of the factors of occupational exposure to incidence of injury. The experience gained from this pioneering study should be evaluated and a much larger program of studies should be conducted for some of the major categories of occupational injuries.

Application of Ergonomics to Work Design

Chaffin (1982) has discussed the essential relationship which should exist between the fields of ergonomics and occupational safety, i.e. further advances in occupational safety will come as a result of the application of ergonomic principles to the design of workplaces in industry. The material presented in this paper has demonstrated the value of an ergonomically-based causal model for occupational accidents. To implement this approach will require a much greater understanding and application of ergonomic principles than exists in industry today. A program should be developed by NIOSH and OSHA with the following elements.

1. Development of specialized training programs to be offered to industry covering the application of ergonomic principles to workplace design. The program could be developed by NIOSH and implemented through OSHA's program of New Directions Grants for different industries.

2. Using the epidemiological model to identify major areas of injury incidence in the work environment, priorities should be established and a program of ergonomic research initiated to develop injury prevention methods/standards for these priority areas.

3. NIOSH and OSHA should sponsor the necessary research to establish standards which have a sound ergonomics basis as well as reviewing the possibility of requiring an ergonomic analysis of major categories of jobs where injuries are prevalent such as overexertion, falling, etc.

Human Error Rates

As noted in the foregoing discussion of new system safety approaches which can be applied to reduce occupational injuries, a great deal of information remains to be collected regarding human error rates for various types of tasks. The absence of such information seriously limits the applicability of systems safety methodology to some of the more important occupational injury problems. Only in areas of exceptionally high risk such as atomic power plants, space and military applications have any significant studies been completed for human error rates in performing some of the tasks commonly found in industry. It is necessary that such error rates be determined if a realistic assignment of tasks between men and machines is to be accomplished with an acceptable degree of risk for the worker. Of course, in areas such as the operation of atomic power plants, there is also a risk which extends beyond the exposure of the worker to the exposure of the general population.

Application of Systems Safety Methods

Given that realistic information can be collected regarding human error rates in performing a variety of tasks in industry, a major emphasis needs to be given to the application of systems safety methodology to a variety of typical industrial systems in order to demonstrate the applicability of this methodology and its potential for improving safety in the workplace. A number of successful demonstration programs would be very useful in encouraging industry to make the necessary investments to train their personnel and the analysis necessary to apply systems safety techniques to their operations.

Accident Investigation Methodology

It is clear from the information which has been presented that additional effort must be given to the development of suitable methodologies for collecting causal information for occupational accidents and injuries. Far too much of the information presently collected is utilized for purposes other than determining the steps which might be taken to prevent future occurrences of the accident. In particular, the application of the principles of ergonomics to the analysis of human/machine systems will suggest new types of information which should be collected in the future.

Costs of Accidents and Injuries

In order to provide the necessary economic incentives for improving safety in the workplace and reducing the injuries to workers, it is necessary that studies be completed in a variety of industries which document the true cost of an accident, including both direct and indirect cost as discussed earlier in this paper. Methodologies should be presented for industries to use in estimating these costs as a proportion of the direct cost of an accident. If such cost information is made more readily available, the likelihood will increase that managers will become more interested in improving safety in the workplace, especially if safety and health performance can be incorporated as a significant part of the manager's overall performance evaluation.

Risk-Taking Behavior

Despite a great deal of progress in the education of workers regarding their responsibility for safety and health in their workplace, a serious lack of information continues to exist regarding the rationale which workers use to assess the risk of an accident or injury as a result of their unsafe behavior in a given manner at their workplace. An improved understanding of the way in which workers go about making decisions to accept a given level of risk in their workplace would provide very useful information in developing training programs to combat this risk-taking behavior.

Safety and Productivity

It is widely believed by many workers as well as managers that a safe and healthful workplace is also a workplace with a higher level of productivity than one where the workers are concerned about the risk of injury or illness resulting from their work. Further research needs to be conducted to determine if this belief is supportable by specific information which can be used to convince managers that it is in their self interest to provide a safe and healthful workplace.

Training of Engineers, Architects and Industrial Designers

Finally, the training and education of engineers, industrial designers and architects should be reviewed and programs developed to incorporate more information into their education regarding the safety and health impacts of their designs. The typical curriculum for programs in engineering, industrial design and architecture incorporate only a minimum amount of information regarding the safety and health impacts of design. Model courses and other special training programs should be developed and made widely available to educators in these fields of study.

EXAMPLES OF FIXED BARRIER GUARDS

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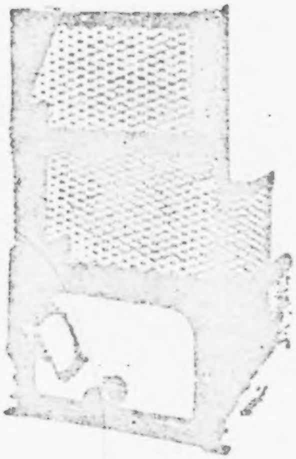

Illustration No. 10

Illustration No. 11

Illustration No. 12

Illustration No. 13

Figure 4: Examples of Machine Guarding

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COMPUTER-TELECONFERENCING AS A MECHANISM TO IMPROVE INFORMATION TRANSFER FOR WORKPLACE SAFETY AND HEALTH

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Computer-Teleconferencing as a Mechanism to Improve Information Transfer for Workplace Safety and Health

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In the area of communications and information, Dr. Priest coordinated a NIOSH/MIT computer-teleconference on health/safety issues and has developed computer-communications software for improving the transfer of information from researchers to others. And in the area of trade-secrets he has authored "Toxic Substances: Investigation of the Conflicts in Goals between Public and Private Interests in Trade Secret Data" for EPA.

Computer-Teleconferencing as a Mechanism to Improve Information Transfer for Workplace Safety and Health

1. Introduction to Computer-Teleconferencing

A computer-teleconference is a computerized form of communicating among a group of people. It is much like a situation where each person writes a "memorandum" to a central file and where each person checks the central file to see what has been entered since he or she checked last. The "memorandums" are kept in chronological order and either the memorandums can be all mixed together or they can be kept separate under some topic name.

The computerized version of this exchange is called computer-teleconferencing. The "memorandums" are typed at computer terminals and are stored at the central computer. The memorandums are checked by the "participants" of the conference through the same computer terminals. Thus, while the storage and access is centralized, the participants can be separate both geographical and temporally. With the availability of computer access ports in all major cities of the country and in most foreign countries, participants can "conference" without need of travel. Since the participants do not communicate by speaking to each other, but by reading what has been left in the central file, the participants can exchange information at different times of the day or night without regard to each other's schedules.

Computer-teleconferencing contrasts with two other major forms of teleconferencing -- video and audio. In video teleconferencing, the exchange occurs at the same time and geographically separate participants see each other on video monitors. (Many major corporations and some government agencies provide video teleconferencing facilities for their employees.) Audio-teleconferencing is an aural exchange between geographically separated participants. Each person has earphones and a microphone to communicate with. Computer-teleconferencing can occur within a designated period of time and is then referred to as synchronous computer-teleconferencing. In this mode, messages are sent and received continuously at the terminal. In the more common non synchronous mode, a participant reads waiting messages at the terminal and then composes responses, entering them into the exchange -- responses to his or her messages are read at the next "session."

1.1 General Use of Computer-Teleconferencing

Computer-teleconferencing arose out of the public sector. In 1970, the White House Office of Emergency Preparedness (OEP) needed to coordinate the development of wage-price guidelines. To accomplish this task, Murray Turoff and others at OEP developed the Emergency Management Information System and Reference Index (EMISARI)[1,2]. Using this computer-teleconferencing system the ten regional offices of the OEP shared information in the development of both the initial guidelines and the emerging modifications and interpretations.

Turoff joined the Department of Computer and Informational Sciences of the New Jersey Institute of Technology and by the mid 1970's had developed the Electronic Information Exchange System (EIES). This system was accessable to outside groups on a time-sharing basis and became the key resource for many public experiments in the use of computer-teleconferencing. Several of the specific uses of teleconferencing described in greater detail in Section 2 were performed on EIES (Politechs/Legitech and the NIOSH-OSHA exchanges). EIES has also been the site of professional-society committee deliberations such as those of the Instrument Society of America. In another exchange, 10 hepatitis experts used EIES to organize a new database, the Hepatitis Knowledge Base that is now available for downloading into physicians' microcomputers[3]. In 1980, Dr. Dauerman of the Law and Technology Center at the New Jersey Institute of Technology used EIES with 16 other participants to discuss siting and implementation of hazardous waste facilities[4]. Also in 1980, Sheridan and others organized an international conference using both the teleconferencing facilities of EIES and the "electronic-journal" (on-line writing of articles) to discuss the topic of "mental workload" (the load of various mental tasks)[5].

Other groups interested in computer-teleconferencing developed similiar systems during the 1970's. Some of these developments grew directly from EIES while others were developed by people who generally appreciated the potential of the technology. At the Institute for the Future, Robert Johansen and Jacques Vallee developed the basis for a system called PLANET and together with Kathleen Spangler the three performed studies on the effectiveness of computer-teleconferencing as an alternative to other forms of communication[7,8,9]. Jacques Vallee founded Infomedia Corporation in 1976 and markets a product derived from PLANET called NOTEPAD. Bechtel Corporation uses NOTEPAD to coordinate their engineering teams that are geographically separated from the home office. NOTEPAD is currently used through the Infomedia computer by 120 users, primarily private corporations. Some 70 of these are nuclear power utility companies who use the facility to coordinate their activities through an umbrella organization called INPO (Institute of Nuclear Power Operators) organized after the Three Mile Island incident.

A major outgrowth of the EIES experience has been developed by Chandler Stevens and others of Participation Systems, Inc.[10]. Their system called PARTICIPATE is available on the Readers' Digest Computer Utility — The Source[11], and most recently on the time-sharing network DialCom (owned by ITT and servicing many government agencies as well as businesses). Both the Systems Exchange and the NIOSH/MIT exchange described in Section 2 were conducted using PARTICIPATE on the Source computer.

Internationally, major interest in the technology has been shown by the International Institute for Applied Systems Analysis[12,13] in Laxenburg, Austria. Their first experience was with EIES and more recently they have developed an in-house system. Using various information network links they see the capability as a means to tie together people in locations throughout Europe and the U.S. including those with access to nodes (central computer information gateways) in Moscow, Prague, Budapest, Vienna, Frascati, Pisa, and with EURONET, and the U.S. Tymnet-Telenet network[14]. Also, the Swedish National Defense Research Institute developed a system called COM[15] which is available only under licensing.

In addition to these systems, there are at least five others that provide related technology on a subscription basis. These include CONFER (Advertel Communications, Ann Arbor, MI), HUB (Institute for the Future, Menlo Park, CA), Genie (Data Dynamics, Portland, OR), MTX (Matrix Transaction Exchange, Cross Information Co., Boulder, CO), and Augment (Tymshare, Cupertino, CA)[16]. It is not known how many private corporations have developed or licensed computer-teleconferencing systems for their in-house use.

1.2 Use of Computer-Teleconferencing for Health and Safety

The major use for health and safety has occurred as part of the use of teleconferencing by state legislatures. With National Science Foundation funding beginning in 1978, about 20 state legislatures used EIES under an umbrella system called LEGITECH (see discussion below). The purpose of the exchange was to provide better technical information to state legislatures. Subjects of exchange included roadway safety, air quality, and waste treatment.

In addition to the state legislatures, federal laboratories participated in the exchange to meet their legislated mandates to help state and local governments. One of the federal participants was the National Institute for Occupational Safety and Health (NIOSH). Subsequent to their involvement in LEGITECH, NIOSH conducted two computer-teleconferences to coordinate their responses to rulemaking by the Occupational Safety and Health Administration (OSHA). Most recently, a computer-teleconference was conducted with PARTICIPATE (on the Source computer) including the MIT Center for Policy Alternatives, NIOSH, and others, to discuss the potential role of further computer-teleconferencing to aid NIOSH in priority setting and in gathering information on particular hazards. The details of the NIOSH experiences are described below in Section 2.4.

2. Selected Teleconferencing Systems and Exchanges

2.1 Choice of Selected Systems and Exchanges

Computer-teleconferencing may be of use for improving safety and health through both public and private exchanges (public — involving government or interest groups; private — firm-to-firm, now typically through trade publications). Therefore, the specific systems and exchanges reviewed here were chosen to reveal the potential for both types of exchanges. The discussions on Legitech/Politechs and the use by NIOSH examines the use of teleconferencing by public government agencies with mandates to promote health and safety. In the case of private exchanges, there has been no known use of computer-teleconferencing to regularly share information between or among corporations for health and safety purposes, but one known case of a major corporation that has used teleconferencing internally for improving information transfer for workplace safety and health. To further understand the potential for private exchanges between firms, the SYSTEMS exchange (an exchange among firms to share information about computer systems) is described to understand under what conditions firms share information with other firms using this medium.

The diffusion of innovation literature provides some insight into the reasons new technology is adopted (or not adopted) by potential users. Three general reasons are important to our discussion: 1) When technology is unfamiliar, no matter how useful, it takes time to be adopted (there is a typical diffusion process where "leaders" first adopt the technology and others adopt as the success of the technology becomes more evident), 2)

When new technology is cumbersome, the minuses can outweigh the pluses and diffusion is delayed until the technology becomes more "friendly," and 3) Characteristics of the new technological environment, in this case more fluid communication, can reveal institutional barriers to its diffusion -- in the case of private exchanges these barriers include concerns for trade secrets and activities that may be viewed as antitrust related.

2.2 Review of Selected Systems and Exchanges

In discussing the selected exchanges a brief history is provided for context. Following this, aspects of the exchange relevant to assessing the potential for computer-teleconferencing as a mechanism to improve information transfer for workplace safety and health are presented. Some of the exchanges discussed here are on-going, some are in a growth phase, and others are in transformation. In general, we find many of the characteristics of groups adopting the new technology exhibiting "hunting" -- the behavior of systems to reestablish equilibrium when influenced by an outside effect, in this case the introduction of computer-teleconferencing. During the hunting process, different patterns and variations are tried until an optimal mixture of activities is reestablished.

2.2.1 Legitech/Politechs

In 1978 the National Science Foundation supported the development of a computer-teleconference for state legislatures. It was held on the Electronic Information Exchange System (EIES) at the New Jersey Institute of Technology. As its name, Legitech, implies, it was to aid in the transfer of technical information among the staff of state legislative bodies. Some twelve legislatures actively participated and were joined by a dozen Federal agencies (including the White House and members of the Federal Laboratory Consortium) and a mixed dozen of technical professional societies, public interest groups, local governments, and private firms[17]. Another twelve legislatures participated to a lesser extent. As interest grew, an umbrella name, Politechs (Policy and technology) was designated to include the activities of Legitech (Legislation and technology), Localtech (for local governments) and Publitech (for citizen's general interest in public policies).

The impetus for Politechs came from Dr. Chandler Stevens who had twice served in the Massachusetts state legislature. He saw the technology as a means to increase citizen participation and provide a way of forming policy through horizontal, person-to-person communication to supplement top-down decision-making structures. Federal laboratories and NSF funded innovation centers participated to fulfill their mandates to aid state and local legislatures. The fifty Politechs participants represented about 10% of the total users of the EIES system from 1978 through 1980. When NSF funding ran out in 1980, momentum on EIES declined. At first many of the participants continued provided funding to make up the difference, but gradually the state legislatures turned to the National Conference of State Legislatures (NCSL) and are using the Legislative Information System (LIS) there. Unfortunately, LIS does not have the teleconferencing facilities of the EIES/Politechs system and does not permit participation by federal laboratories or others. A number of Federal laboratories and NIOSH maintained interest, but without the state legislatures and with cuts in funding to the innovation center there was no longer the critical mass necessary to sustain the exchange[18].

During the three year period of active use on EIES, there was considerable use and interest among the Legtechs/Politechs participants. The topics of discussion extended over the entire range of legislative interests including the economy, communications, health, and the environment. Among the health related discussions was an exchange on "the incidence of the lung disease Silicosis among foundry workers." The exchange was initiated by the Legislative Office for Research Liaison, House of Representatives, Pennsylvania. Insurance claims were found to be high for the disease and the legislature needed information to assist the foundries and foundry employees. Several important pieces of information were uncovered during the exchange: 1) Dusty aspects of the operation were identified, 2) A Penn State Univ. report on air quality indicated that an olivine-base synthetic sand was a viable alternative to silica-based sand, and substantially reduced silica levels in the foundry, and 3) The roles of OSHA and NIOSH were identified[19].

A key determinate of the success of the exchange was the presence of an "organizer." It was important to have someone whose job was to prompt others, examine the direction that exchanges were taking, and do house-cleaning chores such as weeding out weak responses, writing up notebooks of responses[20], and maintaining the teleconferencing software. In the case of Politechs, this was performed under NSF funding of Participation Systems with Dr. Stevens performing most of the organizer role. When NSF funding was dropped, there was not a cost-sharing structure that took its place that could continue continue to support the exchange.

In summary, Politechs was a technical success but did not achieve stability in its NSF funded form. It is not possible to conclude whether this was because the exchange was not worth the expenses ($200/month per participant) or whether the diversity of participants and the problems of justifying funding for a new "line item" prevented its continuance on EIES. (The National Conference of State Legislatures has been a long standing means by which state legislatures fund a coordinating body.)

2.2.2 National Institute for Occupational Health and Safety

The National Institute for Occupational Health and Safety (NIOSH) has a technical information division that coordinates information activities at NIOSH. Among its many functions the division drafts responses to Occupational Safety and Health Administration (OSHA) rulemaking and is involved in gathering and disseminating information related to NIOSH Criteria Documents. This division was a major participant in the Politechs exchange (see 2.2.1) and continued using computer-teleconferencing in two subsequent exercises -- formulating responses to OSHA rulemaking and an NIOSH/MIT exchange.

2.2.2.1 OSHA Rulemaking

In 1982 OSHA issued Advanced Notices of Proposed Rulemaking for two major regulations. One was on Hazard Communications and related to the labelling of chemicals used by employees in the workplace. The second was on Access to Medical Employee Records and stipulated when medical records were to be kept, who had access to the records and under what conditions.

Dr. Richard Lewis initiated two computer-teleconferences to help compose the NIOSH response to the OSHA notice. Discussions had been held between Dr. W. Curtiss Priest of MIT and NIOSH about the potential use of teleconferencing for this purpose in the early part of 1982. NIOSH conducted the exchange on Hazard Communications between April and June of 1982, and the exchange on Access to Records between July and September of 1982.

About ten NIOSH employees participated in each exchange. For the most part these were different people in each exchange, selected for their expertise and experience on the specific topic. NIOSH purchased a dozen portable terminals ($1000/each) and shipped terminals to each participant. Nearly all participants were unfamiliar with the technology and required about two weeks of interactive training to become conversant with the EIES system. Some of the more difficult aspects were just becoming familiar with a computer terminal and the vagaries of using a telecommunication network such as TELENET. Dr. Lewis reported that people were used to the reliability of telephone service and the occasional failures of TELENET & obscure messages would put many of the participants off[21].

The participants were geographically dispersed. In the first exchange four were located in Cincinnati, two in Atlanta, one in Boston, two in Washington, and one in Morgantown. The participants included Ph.D. toxiocologists, industrial hygienists, chemists, physicians and engineers. A total of 170 comments were made in the first exchange. Many were interactive responses that built up to some resolution. In contrast, some of the participants would not respond for a few weeks and then make one long statement. For the most part, the participants were pleased and the process produced a much greater diversity of information for the OSHA statement.

On the Hazard Communication exchange a major topic was on how the ingredients of a chemical used in the workplace should be labelled. Discussions focussed on the employees' need-to-know about hazards and also on the feasibility witn regard to industry's concern for trade secrets. The exchange came to a resolution to recommend that the ingredients not be listed on the can but be available to the employee on a data sheet.

On the Access to Medical Records a major discussion developed regarding OSHA's proposal to cover only employees exposed to chemicals on a specified list of substances. This was found to be too limited and the consensus of the participants was to include all chemicals for which toxic, mutagenesis, carcinogenesis, and teratogenesis effects have been found, and also the list of chemicals currently under testing.

Dr. Lewis considers the exchanges an unqualified success. The response to OSHA was also composed on EIES and this permitted each participant to read and comment on the final report. The computer costs for operating the Hazard Communication Exchange totaled $2500 and this was only two-thirds the cost of a two day meeting at Cincinnati (including per diem, travel and extra lost work time). In addition, the process helped involve the regional offices in a way that would not have otherwise occurred.

The general result were documents with a wider scope of information and opinion. Instead of being the product of a single person assigned to drafting the OSHA response, it represented the views of the entire group quite well.

However, substantial budget cuts at NIOSH will prevent further use of computer-teleconferencing. Dr. Lewis would like to use the NIOSH in-house word-processing system to duplicate the process, but the capabilities are primitive in comparision to EIES.

2.2.2 NIOSH - MIT/CPA Exchange

In October of 1982 NIOSH agreed to fund computer time to support an exchange including Dr. W. Curtiss Priest at the Center for Policy Alternatives, MIT, and Dr. Richard Lewis at NIOSH. Additional participants were Dr. Chandler Stevens of Participation Systems, Dr. Irving Lerch, Professor of Medical Physics at the New York University School of Medicine, and other volunteer participants. The teleconference was conducted on the Readers' Digest Source Computer with the recently installed computer-teleconferencing software PARTICIPATE.

The exchange served several purposes. It provided a core group -- Lewis, Priest and Stevens -- to discuss opportunities and problems with the technology. Secondly, it provided an opportunity to see what voluntary participation would occur on a computer system with about 15,000 subscribers in total. Thirdly, an in-depth exchange was conducted on the hazards associated with video display terminals (VDT's).

Two general conclusions were reached about the exchange. While the discussion on VDT's involved about a half dozen of volunteer participants including Dr. Lerch with substantial expertise on the radiation concerns, such discussions were unlikely to be of general value to NIOSH. The second conclusion, partly based on the first, was that computer-teleconferencing appeared to be most successful when it was task and deadline oriented. It is not only important to have an organizer (see discussion under 2.2.1) but it was also important to selectively involve participants for the exchange to accomplish a specific task -- whether as an interaction in planning a standard conference or to produce a document or decision.

The exchange continued to the end of the funding period, December 1982. Over a dozen volunteers participated and a total of sixty-five messages were posted. The VDT branch of the discussion generated thirty of the messages. Within the VDT discussion there were two lines of discussion that did not really overlap. One discussion was on radiation and ergonomic effects while the other was on stress and quality of work effects. There were clear divisions of interests and backgrounds.

2.2.3 A Major Corporation System

One of the questions raised in the discussion in 2.1 was how feasible are private exchanges using computer-teleconferencing. To further answer that question the computer-teleconferencing experiences of a major U.S. corporation was investigated. In the course of the discussions with the company it became clear that their use of their system was considered proprietary and many details would not be revealed. While the firm stated they used the system considerably for health and safety purposes, they would not disclose any details about the content or process even as it related to the public concern of health and safety. Since this behavior of the firm is of particular interest to the general feasibility of private exchanges, the identity of the firm will not be mentioned so that this aspect of the discussions can be furthered explored in this paper.

The Corporation is one of the fifty largest U.S. firms and has over 60,000 employees worldwide. In the late 1970's they became interested in the PLANET system (see section 1) and soon had developed their own computer-teleconferencing system. Over 4000 employees use the system and the vice president for R&D considers its use a crucial and integral part of the firm's ability to develop products and manage their operations. One of the major uses is to get leads — "have you seen something about" questions are prevalent. The greatest advantage of the system was its ability to "finesse geography."

One discussion about the system centered about whether employees were reluctant to share "ideas" on the system and how this related to the feasibility of private systems. The general response was that ideas were not usually the types of communication that the system engendered but rather transfering information about already known things. Ideas are presented in face-to-face situations and required "careful listening time."

The system has been used substantially by employees concerned about product safety. Exchanges have occurred in areas of pharmacology and toxocology. Other exchanges have occurred on worker health and safety. When asked about the feasibility of interfirm sharing of information on health and safety, there was a concern for antitrust, restraint of trade issues. Only designated trade associations and public meetings were viewed as acceptable grounds for sharing information.

When asked to elaborate about the ways in which the system has been useful for health and safety, however, the discussion became deadlocked. After internal discussion about the request, the firm refused to disclose anything further, even about health and safety. (On another occasion the firm was to make a presentation about their computer-teleconferencing at a conference only to pull out at the last minute because of company policy not to discuss details about their system in a public forum.) In further discussion it was pointed out to the firm that a system that helped save lives and prevent injuries and illnesses would be of great interest to the public and that some details about its use for this would be helpful. Regardless, the firm insisted on commenting no further.

The firm in this situation has made an implicit trade-off -- between the deaths and injuries that would be reduced by disclosing information about their system and their proprietary business interests and desire for privacy. There is also the possibility that the firm was concerned about disclosing information about product safety discussions that might be "discoverable" in a legal proceeding. On either account, the firm has been a decision between its own self-interests and those of the employees whose working conditions might be improved by this knowledge.

2.2.4 Systems Exchange

The Systems Exchange represents the one of only two known on-going computer teleconference in which participants are sharing information among different firms (the other is the INPO association of utility companies described in 1.). Therefore, while the content of this exchange is not on health and safety matters, the reasons for its existence will help provide further understanding about the feasibility of private exchanges among firms.

At MIT the Center for Information Systems Research (CISR) conducts joint research under the sponsorship of 22 corporations. These include American Hospital Supply, Bank of Montreal, SIGNA, Exxon, General Motors, Honeywell, and Johnson & Johnson. The sponsoring section of these companies are the information systems & corporate strategies groups. About eighty reports have been published by CISR under this sponsorship.

Up until last year the usual mode of exchanging information among the firms has been to come to meetings that are held six times a year. These are opportunities for representatives of the firm, usually high to middle level management, to discuss common problems and solutions.

With the availability of computer-teleconferencing on the Source Computer Ms. Christine Bullen, Assistant Director of the Center, contacted the sponsoring members and organized the Systems Exchange. About half of the members were interested and have obtained an account to participate. Many were motivated to learn about the new technology as well as to share information with others.

In contrast with the example of the private corporation example above, people within these firms are fairly free to share information. This may be partially due to the fact that these firms are the ones that elected to jointly sponsor research through CISR in the first place. Even though firms like American Hospital Supply and Johnson & Johnson are in the same business and though Digital Equipment Corp., IBM, and Honeywell are in the same business, there is an openness to discuss joint problem areas and come forth with solutions. Ms. Bullen suggests they share information about what they are proud of. Only occasionally does a firm announce a development in information systems after being quiet about its development[22]. A flourishing area for discussion on the exchange has been the use of micro-processors in the organization. Questions have arisen as to whether it is a good idea to buy only one type and how quickly should they be introduced.

These are firms that see some advantage to broadcasting for help on a communication medium rather than expecting to get information "solely from databases." In the model of innovation of Prof. Richard Nelson at Yale, there are some firms that share and learn from each other in a cumulative fashion, while others compete in relative silence. What happens in any given case is often a product of the area of business the firm is in -- e.g. semiconductor firms learn and share while pharmaceutical companies generally do not. This suggests that there is no general answer about whether firms will share information in private exchanges but that it at least depends upon the product sector the firm belongs.

3. Value of Teleconferencing for Improving Occupational Health and Safety

3.1 Opportunity and Barriers to Exchange

3.1.1 Evidence

To help determine the value of teleconferencing it is useful to review the strengths and weaknesses of the technology. Johansen has analyzed the literature on this subject and has listed the following strengths and weaknesses[23]:

- Strengths

  1. The written record basic to the computer conferencing medium is crucial for some tasks.
  2. Handwritten messages are more persuasive than video or face-to-face communications.
  3. Computer conferencing allows time for reflection on the topic of conversation.
  4. Access to computer conferencing can make working hours more flexible.

5. Computer Conferencing can be used well as a preface and/or follow-up to a face-to-face conference.
6. Computer conferencing can promote communication among disseminated groups who may not otherwise communicate if the need to communicate is high enough.
7. Participants can obtain more deliberate answers to technical questions, backed up by written facts with less delay.
8. Computer conferencing is perceived as satisfactory for exchanging information, asking questions, exchanging opinions or orders, staying in touch, and generating ideas.
9. Computer expertise is not a prerequisite to effective use of computer conferencing.
10. Lack of typing ability is not a barrier to participation in computer conferencing.

- Weaknesses:

1. Other communication forms allow many more messages to be exchanged in a given time period than does typing.
2. It is sometimes difficult to focus the discussion in computer conferencing.
3. Problems take longer to solve in written modes.
4. Participants are sometimes reluctant to make certain statements in writing.
5. Regularity of individual participation is sometime difficult to enforce in computer conferencing.
6. Managers have a strong preference for verbal and immediate (often unscheduled) communication.
7. Training of new users is very important.
8. Participants must learn new skills to use computer conferencing.
9. The form is vulnerable to poor human/machine interface with both computer networks and computer terminals.
10. The volume of information in a computer conference can sometimes become overwelming on some implementations of the technology.
11. Participants sometimes feel a lack of group interaction.

These strengths and weaknesses have generally been characteristics of all the exchanges discussed in section 2. But with respect to the specific area of workplace health and safety, and the selected systems and exchanges it is useful to further review the opportunities and barriers to exchange.

3.1.2 Costs and Availability

Costs of computer-teleconferencing vary from $7.75 to $60 per hour depending on the computer system, time of day, and telecommunication network. Some systems have group rates that further complicate the picture. In general, the lower cost systems that can are reached through a telecommunication network cost between $14 and $21 an hour during the day. The Source Computer has excellent evening rates, $7.75/hour but its day rates are on the high side at $20.75/hour. Therefore, at current costs one might consider using EIES if most of the usage is during the day and The Source if most of the usage were evening. Ten hours of teleconferencing a month is a typical level of use for a participant -- $150/month per participant for day-time use or $60/month per participant for only evening use.

Two other costs must be considered: 1) A computer terminal (a minimum of $50/month but the device can be used for other purposes or can be part of a word-processing system or micro-computer), and 2) The cost of the organizer of the conference. In many of the uses described above the organizer cost is often covered by the person's general salary.

All major cities and many other locations have telecommunication networks available now by a local telephone call. If the participant is not within local reach of a network connection costs are much higher and the transmission of characters is much less reliable. With the growing use of micro-computers and portable computer terminals, access to equipment is becoming less of a problem but, as in the NIOSH task oriented use, terminals had to be supplied to many of the participants.

As found in the NIOSH use, the cost of computer-teleconferencing is already less than travel costs to accomplish approximately the same interaction. Future costs for computer-teleconferencing will gradually decrease with further competition among both telecommunication network vendors and central computer vendors.

3.1.3 Trade Secret and Antitrust Concerns

As was revealed in discussions about a major corporation system and the Systems exchange, trade secret and antitrust concerns are significant but vary according to circumstance. The exchange among CISR sponsors typified a more open style of information sharing while the case study of a major corporation showed that both trade secret and antitrust concerns could thwart a well intended exchange among industrial hygienists in different firms.

One characteristic of computer teleconferencing that should reduce restraint of trade concerns is the fact that a permanent record of the discussion is always available. While such a record could be used as evidence of antitrust behavior if such were the case, it is much more likely that such a record would keep the discussion open and non-collusive.

The fact that many industrial hygienists publish in trade journals is an indication that trade secret concerns are not completely inhibiting. There might be, however, reluctance by corporations to let employees participate in as fluid and facile a medium as computer teleconferencing until they were able to assess the advantages of sharing in this medium against the possibility of loosing competitive advantage. One could imagine a situation that was superior to publishing in the trade journals -- where sharing was the rule and a "free rider" could be expelled from the exchange by the organizer.

3.1.4 Possible Inducements

Perhaps the major hindrance to the use of computer-teleconferencing is the lack of institutional support. Since the technology is new, it is difficult to obtain funding for the activity as a line item in a contract or on a corporate budget. The need for an organizer also requires redefinition of a person's responsibilities within an organization and financial support for the activity.

NSF funding of the Politechs experience was important to cut across these barriers. Unfortunately NSF funding can only be temporary. A more continuous source of funding is needed for these exchanges to maintain their momentum. One possibility is to work more with existing groups such as the National Conference of State Legislatures, industry associations, labor unions and the National Institute of Occupational Safety and Health. Specific funds might be earmarked for the activity (as in the case of the mandates for federal laboratories to aid state and local government).

It is not clear whether the marketplace will on its own promote the use of computer-teleconferencing for health and safety. It may piggyback on activities that produce a profit but this process is unlikely to provide as much information transfer for health and safety as may be desirable.

At least, the support of additional activities related to health and safety such as the NIOSH use will have high leverage as the experiences of these exercises can be communicated to others who can imitate the process. A result of the Systems exchange is the interest among many of the member corporations in having their own in-house computer-teleconferencing capability.

3.2 Conclusions

In summary the following are concluded from this study:

- Computer-teleconferencing is a powerful medium for sharing information and developing task related products involving information collection and synthesis.
- Computer-teleconferencing is more cost-effective than travel for certain conferencing purposes when the participants are geographically dispersed.
- Initial uses of computer-teleconferencing by both public and private groups are encouraging for future prospects of the technology.
- While there are circumstances where trade secret and antitrust concerns are significant, these are not likely to pose a major hindrance to the application of computer-teleconferencing for health and safety.
- Selective, leveraged funding of computer-teleconferencing for health and safety will help the technology reach its potential in helping to reduce injury and save lives.

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AN INFORM REPORT ON
WORKER TRAINING AND EDUCATION PROGRAMS
IN OCCUPATIONAL HEALTH AND SAFETY

Part I: Major Types of Programs

Prepared for
U.S. Congress,
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INTRODUCTION

In fulfillment of its contract with the Office of Technology Assessment of the U.S. Congress, INFORM has completed the following tasks:

a) identification of four major types of worker education and training programs in occupational safety and health;

b) case-study reports on: the International Lead Zinc Research Organization (ILZRO), Local 199, United Automobile Workers (UAW) and General Motors of Canada in St. Catharines, Ontario, and Local 201, International Union of Electrical Workers (IUE), Lynn, Massachusetts.

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PART I

FOUR TYPES OF TRAINING AND EDUCATION PROGRAMS IN OCCUPATIONAL SAFETY AND HEALTH

The Survey Sample

INFORM has surveyed 40 education and training programs in occupational safety and health, in order to determine:

a) major types of programs;

b) key features of each program type;

c) what organizations sponsor these programs;

d) what the programs have accomplished.

The 40 programs in the survey represent two-thirds of an original survey sample of 63, and include 8 business firms and trade associations, 10 unions, 4 hospital-based programs, 8 university-based programs, 6 Committees (or Coalitions) for Occupational Safety and Health (COSH groups) and 4 miscellaneous educational and resource centers.

INFORM selected its survey sample on the basis of:

a) recommendations by labor educators, trade unionists, environmental groups, business officials, and the Office of Technology Assessment;

b) program descriptions of 1980 and 1982 recipients of New Directions grants, awarded by the federal Occupational Safety and Health Administration (OSHA);

c) descriptions of organizations in the National Inventory of Occupational Self-Help Groups, prepared by the Institute for Labor and Mental Health, for the National Institutes of Mental Health - Center for Studies of Metropolitan Problems, U.S. Department of Health and Human Services.

Program Types

Every program included in the INFORM survey aims to teach workers -- either directly or by teaching the teacher -- to assume responsibilities along with management for improving the workplace. INFORM distinguishes four major program types according to the specific duties the workers are taught and expected to perform as a result of the program.

The major types of programs identified are: Fundamentals programs, Recognition programs, Problem-Solving programs and Empowerment programs.

The following chart shows the distribution of programs surveyed by INFORM according to program type and according to the type of organization that develops and administers the program.

Type of Sponsoring Organization	PROGRAM TYPE				
	Fundamentals	Recognition	Problem Solving	Empowerment	Totals
Businesses	5	3			8
Unions		5	5		10
Universities		3	5		8
Hospitals		3	1		4
COSH				6	6
Educational Resources			3	1	4
	5	14	14	7	TOTALS

INFORM considered several criteria for distinguishing major types of worker education and training programs in occupational safety and health. These included (a) program structure; (b) program content; and (c) program goals. However, only the one used here -- that is, the role the worker is to be trained or educated to play in identifying and controlling plant hazards -- allowed us to compare programs sponsored by very different types of institutions.

The distinction between "training" and "education" is relevant to the distinctions INFORM makes among major program types, but it is not essential to understanding their major features. See Appendix A for a discussion of the relation of program types to "training" and "education."

A description of each of the four major types of programs follows. INFORM does not argue that any of the four is the best. The categories are related logically; however, they are like a series of steps an ignorant, unskilled worker might be imagined to take in learning to participate ever more broadly in identifying and controlling workplace hazards. The worker would first have to be skilled in the content of Fundamentals programs before proceeding to the skills taught by Recognition programs; Recognition programs would prepare the worker for learning Problem-Solving techniques; and finally, Empowerment programs would educate the worker to participate broadly in social and political activities outside the workplace.

I. FUNDAMENTALS PROGRAMS

Fundamentals programs aim to involve workers in the following worksite safety and health activities:

- performing the job safely and in a prescribed manner. This means properly handling, using, and storing dangerous materials and tools; and properly operating, handling, cleaning and maintaining tools and machinery;
- using protective devices such as masks, respirators, safety goggles, gloves;
- adopting proper personal hygiene and getting medical checkups or examinations;
- knowing what to do in case of an emergency.

In order to explain why particular protective actions are necessary, Fundamentals programs give workers information about the nature of specific hazards encountered on the job and about symptoms of exposure or injury.

Survey Findings

All Fundamentals programs in the INFORM survey are administered by business organizations, i.e., 3 business firms and 2 trade associations. Of these 5 programs, 4 teach supervisors, public health employees, or other "keypersons" (as one respondent called them) to convey information and skills to workers. In the fifth case, the health and safety staff of a company instructs both workers and supervisors.

The "major program objective" most frequently listed by respondents from Fundamentals programs is "reducing costs of worker injury and illness" (or "reducing worker compensation claims"). The second most-commonly mentioned objective is to "motivate management," educate management," or "turn on management," to take a more active role in improving workers' safety and health.

No respondent from a Fundamentals program mentions, as a major program objective, teaching workers to take an active role in worksite safety and health programs. In the context of program objectives, workers are referred to as persons "to be protected."

Example of a Fundamentals Program: Gray Tool Company

An example of a Fundamentals program is the safety training program of the Gray Tool Company of Houston, Texas. Gray Tool, a manufacturer of heavy machinery, requires its 800 workers and all its supervisors to be instructed in basic safety methods and protection.

A permanent health and safety staff of three individuals conducts Gray Tool's program. The training involves showing films and distributing literature at informal gatherings of workers and supervisors who meet during work hours on company time.

Gray Tool's program emphasizes accident awareness and stresses "individual responsibility for one's own and fellow employees' safety." Gray Tool instructs supervisors, but not workers, in inspection and accident-investigation techniques, and in job-safety analysis.

The chart below summarizes the basic elements of a Fundamentals program and lists examples for three out of the four of these elements from Gray Tool's program.

Fundamentals Program	Example: Gray Tool
Fundamentals programs convey information and skills to workers, enabling them to:	Gray Tool offers instruction for workers in:
1. Perform the job safely	1. Proper lifting techniques
2. Use protective devices and techniques	2. Eye protection Use of respirators Hoist operating training Sling inspection training
3. Adopt proper hygiene and health care	3. Hearing conservation
4. Learn emergency procedures	4. Not part of Gray's program

One indication of the effectiveness of Gray Tool Company's safety training program is the company's acceptance in 1982 as a participant in OSHA's Voluntary Protection Program. Another indication is the company's record of 250,000 consecutive man-hours worked without lost-time injury.

II. RECOGNITION PROGRAMS

Recognition programs aim to prepare workers to participate in a broader range of worksite safety and health activities than do Fundamentals programs. In addition to instructing workers how to perform their jobs safely, use protective equipment and adopt good hygiene and health habits, Recognition programs aim to involve workers in the following activities:

- recognizing many different health and safety hazards present in the workplace;
- understanding different methods available for hazard control or elimination;
- understanding rights and responsibilities under the law, e.g. right-to-know laws in several states;
- collecting information about hazards, e.g. chemical identity of workplace substances, symptoms associated with exposures, exposure levels;
- observing or informally inspecting the workplace for potential hazards;
- reporting hazards or potential hazards to appropriate individuals or committees.

Survey Findings

Of the 14 Recognition programs in INFORM's survey, 3 are conducted by business organizations, 5 by unions, 3 by universities, and 3 by hospitals.

In answering INFORM's question concerning major program objectives, 10 of 14 respondents mentioned teaching workers to recognize hazards as a primary objective. Examples of specific responses of four respondents are the following:

- "to teach workers to use various forms and worksheets for estimating exposure levels;"
- "to train workers and employers how to recognize and prevent occupational disease;"

- "to develop skills in identifying specific hazards;"
- "to increase awareness of preventive measures possible by changing the work process or using protective equipment."

Example of a Recognition Program: International Brotherhood of Painters and Allied Trades (IBPAT)

In 1982 the IBPAT instructed and equipped 126 field instructors who reached about 25,000 union members through workshops, conferences and lectures -- with information about specific hazards and means of preventing injury and illness among workers exposed to them.

The IBPAT program is used by local unions and by vocational or trade schools that offer courses to workers and local union officials. The program is tailored to meet the needs of specific groups of workers for instruction about specific hazards.

Instructional materials prepared by IBPAT include videotape modules, a quiz book, and a course book. These materials are designed to complement lectures as well as to stimulate class discussion.

The chart below summarizes the basic elements of a Recognition program and lists examples of 4 out of 6 of these elements from the IBPAT program.

Recognition Program	Example: IBPAT
Recognition programs convey information and skills to workers, enabling them to:	The IBPAT program, for the use of local unions and trade schools, includes materials and course plans for instructing workers in:
1. Recognize different workplace hazards	1. Recognizing and understanding: - Exposure to silica, lead, asbestos, and carbon monoxide - Causes of accidents in the glazing trade - How harmful substances enter into the body and what their effects are - Symptoms of neurological, respiratory, digestive, and circulatory disorders, and what substances are believed to cause these symptoms
2. Understand the different methods of control or elimination of hazards	2. - Control measures for silica, lead, and toluene disocynite - Using personal protective equipment for abrasive plasters - Engineering controls, administrative controls, and work-practice controls for asbestos - Selection of the proper respirator for different hazards, such as asbestos, and isocyanate vapors

Recognition Program (continued)	Example: IBPAT (continued)
3. Understand workers' and companies' rights and responsibilities under OSH Act	3. Worker and company rights and responsibilities under the law regarding monitoring, recordkeeping, medical examinations, OSHA complaints, NIOSH health hazard evaluations
4. Collect information about hazards	4. Using: - Permissible Exposure Level charts to estimate a substance's toxicity - The IBPAT/OSH Dilution Ventilation chart to determine ventilation requirements
5. Observing or informally inspecting the workplace for potential hazards	5. (Providing instruction is the responsibility of the locals)
6. Reporting hazards or potential hazards to appropriate individuals or committees	6. (Same as above)

IBPAT's program does not offer instruction in observing the workplace for hazards and reporting hazards to appropriate individuals or committees. This training is necessarily site-specific and must be undertaken, not by the international, but by local unions or trade schools familiar with particular workplaces and procedures.

IBPAT reports that its program has had a "statistically significant impact on collective bargaining." According to an IBPAT evaluation of its FY 1982 activities, 5 out of 10 locals or district councils that completed the IBPAT program prior to negotiations of their contracts, secured provisions for health and safety committees. Among affiliates that did not receive IBPAT instruction, only 3 out of 10 secured positions establishing health and safety committees.

The IBPAT program evaluation also showed that 27 percent of those affiliates that have completed the program won provisions for training programs in their new contracts. This compares with only 10 percent of affiliates that did not undertake the program.

III. PROBLEM-SOLVING PROGRAMS

The general objective of Problem-Solving programs is to equip the worker with information and skills necessary to participate in solving problems of hazard recognition and control. These problems may arise for a variety of reasons, including:

- inadequate information available to unions or management about hazards or the effects of exposure;
- mechanisms (such as collective bargaining or the use of OSHA complaints) that are inadequate as a means of addressing occupational health and safety problems.

Problem-Solving programs usually provide the basic instruction and training that form the core of Fundamentals and Recognition programs. In addition, Problem-Solving programs prepare workers for the following activities:

- helping to solve problems that arise on the shop floor, in an ongoing, regular way, by use of union and management resources and mechanisms;
- exercising legal rights when necessary and practical, to bring outside agencies, especially OSHA and NIOSH, into workplace to help address hazards.

In order to perform these activities effectively, workers must learn to:

- ask questions about work processes and materials so as to assess for themselves whether hazards have been adequately identified;
- judge the effectiveness of alternative methods of hazard control.

Survey Findings

Of the 14 Problem-Solving programs identified by INFORM, 5 are administered by unions, 5 by universities, 1 by a hospital, and 3 by independent educational and resource centers.

In responding to INFORM's question concerning major program objectives, the Problem-Solving programs emphasized teaching workers to use particular mechanisms to address workplace problems. Examples of seven responses appear below:

- "to use trade-union skills (organizing, informing, negotiating), outside agencies, and other strategies to change working conditions;"

- "to provide workers and their local representatives the necessary information to represent themselves before various regulatory agencies, both federal and state;"
- "teach workers to gain access to the OSHA network;"
- "to support (with technical assistance training and educational materials) union efforts to improve health and safety conditions in workplaces;"
- "to assist workers in becoming more effective in dealing with their employers;"
- "to provide unionists with skills and knowledge necessary to address workplace health problems (using all recourses -- legal, collective bargaining, etc.);"
- "to incorporate health needs into collective bargaining agreements."

Example of a Problem-Solving Program: Labor Occupational Health Program (LOHP) at the University of California, Berkeley.

The LOHP offers a variety of programs and services, including

1) formal education and training courses;
2) workshops and conferences;
3) plant walk-throughs to assist in hazard identification;
4) off-site technical advice;
5) legal advice;
6) assistance in collective bargaining; and
7) administering a resource center for public use.

In 1982, the LOHP instructed over 800 workers and union officials in its courses, workshops, and conferences. It provided 4,000 workers and union officials with educational and training materials.

In addition to providing instruction typical of Fundamentals and Recognition programs (using lecture-discussion format and audio visual materials), the LOHP places special emphasis on teaching the problem-solving skills listed in the chart below:

Problem-Solving Program	Example: LOHP
Problem-Solving programs convey information and skills to workers to enable them to:	LOHP offers the following programs to instruct workers and union officials in problem-solving skills:
1. Take an active role in seeking solutions to problems on the shopfloor	1. - "Training for joint committees (such as an annual course for the OCAW and petrochemical companies in the [Berkeley] area)"; - A conference on workers compensation held on February 25-26, 1983 for workers and trade unionists; - Workshops on "Collective Bargaining on Health and Safety"; - "A dozen or so steward training (sessions) in health and safety for diverse unions."
2. Exercise legal and contractual rights and ensure management compliance to laws and contractual agreements.	2. - Conference on California right-to-know law, held on October 1, 1982, and attended by 150 union and management representatives, professionals, and students; - "Small workshops to aid in the implementation" of the state right-to-know law.

IV. EMPOWERMENT PROGRAMS

Of all the major program types identified by INFORM, Empowerment programs aim to equip workers with the broadest range of skills and to involve them in the most active social and political roles.

Empowerment programs entertain a vision of a fully active, creative workforce, that participates fully in determining the conditions of the workplace. This goal is summarized in the twin aims of Empowerment programs:

- to prepare workers to defend their rights;
- to teach workers how to expand their rights.

The major assumption underlying Empowerment programs is that the goals of cleaning up hazardous worksites and ensuring the health and safety of workers requires a substantial transfer of political and economic power to workers and their unions.

In order to educate workers to play a broad social and political role, Empowerment programs must either instruct workers in the entire range of skills and knowledge offered by Fundamentals, Recognition, and Problem-Solving programs -- or they must work to ensure that such training is provided to workers by unions and/or management.

Survey Findings

In the INFORM survey, 6 out of 7 Empowerment programs are conducted by Committees or Coalitions for Occupational Safety and Health.* One Empowerment program is conducted by a non-profit educational and resource center.

The expansive political focus of Empowerment programs is apparent in the following descriptions of program objectives listed by four Empowerment respondents to INFORM's survey:

- "empowerment of workers to deal with problems at work;"
- "give safety committee members and local union officials and stewards skills in observing and interpreting air monitoring and medical tests; tracking trade names; devising engineering control methods, negotiating effective health and safety contract language;"
- "empower workers and their unions to win safe and healthful working conditions; have more control over their working conditions;"
- "empower workers with the skills and the confidences they need to improve the safety of their workplaces through their collective action."

Example of an Empowerment Program: Unidentified COSH Group

Several dozen local unions, representing over 50,000 workers, and more than 150 individuals, including union officials, workers, health and safety professionals, lawyers, and doctors are members of this COSH group, which asked not to be identified.

The following list of activities illustrates how this COSH group puts the broad mandate of Empowerment programs -- to defend and expand workers' rights under the law -- into practice.

This COSH group

- publishes and distributes materials about specific hazards and specific methods of hazard-control and worker protection;
- organizes and conducts workshops, conferences and courses designed to train and educate workers in a variety of subjects from specific hazard recognition to labor strategies such as building a strong safety and health committee and winning good contract language on safety and health;

*COSH groups are coalitions, organized at the municipal, regional, or state level, and usually include as members: trade unions as the strongest base of support; health professionals and labor educators; unorganized workers and other community members. A number of COSH groups also include environmentalists. COSH groups have broad programs that combine education and training of workers to address specific workplace hazards, technical assistance (providing information) and advice, and political action.

- provides technical assistance to workers about the right to refuse dangerous work, their right to call in OSHA;
- provides technical assistance to workers regarding the process of workman's compensation;
- helps workers and unions prepare testimony for legislative and regulatory hearings;
- organizes workers and unions to participate in changing laws, especially those concerning workman's compensation and workers right-to-know;
- encourages and promotes the alliance of workers and unions with other community groups, especially environmentalists.

COMPARISON OF PROGRAM TYPES

Responses to INFORM's survey questionnaire indicate that Problem-Solving and Empowerment programs are more likely than Fundamentals and Recognition programs to:

- have multiple sources of funding;
- place more importance on workers' reports as a source of information in the preparation of course materials and activities;
- be involved in right-to-know campaigns;
- be affiliated with, or cooperate with a wide variety of groups outside the workplace.

The distribution of responses for each of these categories is included in Appendices B-E.

PROGRAM ACHIEVEMENTS

The following table summarizes the major program achievements by program type, as reported to INFORM on the survey questionnaire. Not surprisingly, achievements most frequently mentioned are those directly related to teaching: i.e., developing courses and materials and training people.

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MAJOR PROGRAM ACHIEVEMENTS [Listed according to program type]

PROGRAM TYPES	NA	Improving workplace conditions (as indicated e.g. by decline in injury rates)	Developing courses and materials	Training people; providing technical assistance	Changing attitudes of workers, management, public	Changing Institutions (e.g. introducing new program to union or company; forming new committee)	Participation in changing laws or regulations
Fundamentals (5)		2	5	1	1		1
Recognition (14)	3	2	10	10	2	2	1
Problem Solving (14)		4	8	8	1	6	1
Empowerment (7)			4	2	3	2	3
TOTALS	3	8	27	21	7	10	6

Note: All respondents were asked to list their "major program accomplishments" (up to 5). Therefore the number of answers for each program type is considerably larger than the number of respondents.

MEASURES OF ACHIEVEMENT

Out of 37 programs responding to the question concerning measures of achievement, only 10 offer quantitative measures of improved working conditions and/or reduced illness or accident rates as evidence of the effectiveness of their programs. Another 5 respondents indicate strongly skeptical attitudes toward quantitative measures for the following reasons:

- "the decline in incidence of job-related injuries or disease can never be directly attributed to training, unless a formal study is undertaken;"
- "decline in incidence of job-related injuries or disease is extremely difficult to measure, and once this is measured it is difficult to attribute to a particular program;"
- "job illness and injury rates cannot be accurately measured because no data base has ever been established in the U.S.;"
- "we do not have truly an effective evaluation tool to measure this;"
- "cannot quantify this -- I don't think statistical declines in disease and injury prove much, even if it were the case, what with speedups and changes in reporting standards".

Out of 37 programs responding, 29 indicate that they evaluate their programs or survey students' reactions to courses. New Directions grantees are much more likely to undertake either program or student evaluations than non-grantees. Of 26 recipients of New Directions funds, 23 conduct some type of evaluation; of 11 non-recipients, only 3 conduct either program or course evaluations.

The explanation for this difference lies, most likely, in the procedure required by the OSHA for funding applications.

CONCLUSION: MORE EVIDENCE IS NEEDED TO DETERMINE WHICH TYPE OF PROGRAM IS BEST SUITED TO WHICH WORKPLACE

INFORM's survey does not provide sufficient evidence to determine which program types might be most appropriate for which workplaces or workforces, but the following factors would probably affect such a determination:

- education and degree of organization of workers;
- nature of worksite hazards;
- speed of technological and process changes in the workplace;
- degree of trust and cooperation between workers and management;
- nature of the surrounding community; i.e., the extent to which workers and unions have strong ties with organizations outside the workplace;
- laws and regulations governing workplace conditions;
- policies and personnel of agencies enforcing safety and health laws and regulations.

Appendix A

A Distinction Between Training and Education

The degree to which workers must be trained or educated depends on the role they are expected to assume in improving workplace conditions.

Training, as INFORM uses the term to apply to safety and health programs, is instruction in known hazards, and in established methods of worker protection. It emphasizes physical procedures and skills, such as keeping a shop floor free of debris, or using and cleaning respirators. Training gives answers to workers and expects them to learn and apply them. Training is the logical foundation of all worker participation in identifying and controlling workplace hazards.

Education is instruction designed to teach workers how to analyze and respond to new circumstances and unforeseen problems. It prepares the worker to identify potential hazards, to request and/or collect information about hazards, to seek remedies to eliminate or control hazards. These remedies may involve use of formal grievance procedures or OSHA inspections. They may involve the worker in suggesting new engineering or work techniques. They may prepare the worker to become actively involved in trying to change laws or regulations. Education seeks to impart mental or intellectual skills. It prepares the worker to ask questions and to identify and solve problems.

In general, among the four program types identified by INFORM, the narrower the role the worker is expected to assume, the more the program of instruction consists of "training." The broader the role, the more the instruction consists of "education." The following diagram suggests how the proportion of worker training relative to worker education differs among the four program types.

<———————— Increasing degree of training

FUNDAMENTALS----------RECOGNITION----------ENFORCEMENT----------EMPOWERMENT

Increasing degree of education ————————>

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Appendix B

Sources of Funding - 1982

Question 35 of the INFORM survey reads:

"What are the major sources of funding for your current health and safety work?"(Indicate estimated percentages for each.)

_________% Dues

_________% Contributions

_________% Institutional Support

_________% Fees for Consulting

_________% Government Grants

_________% Other (please specify)

The responses, broken down by program type, are summarized in the table below.

Sources of Funding - 1982

Program Type	35% or more institutional	35% or more dues	35% or more government	3 or more sources	No response
Fundamentals (5)*	4		2		
Recognition (14)*	5	4	8	4	1
Problem-Solving (14)*	5	3	6	5	
Empowerment (7)*			4	4	1

*Number of organizations included in the category.

Appendix C

Importance of Workers and/or Union Reports as a Source of Information

Question 16 of the INFORM survey asked the participants to:

"Please rank the sources of information listed below in order of their importance to you in preparation of courses and materials."

__________Workers' self-reports and/or union reports (please specify)

__________Newsletters, brochures, pamphlets published by other organizations. The two used most regularly are:
1.
2.

__________Newspapers. The two used most regularly are:
1.
2.

__________Journals or magazines. The three used most regularly are:
1.
2.
3.

__________NIOSH reports or statistics

__________OSHA reports or statistics

__________Other government reports or statistics (please specify)

__________Other

The following table shows the distribution of responses to the question by program type.

Importance of Worker and/or Union Reports in Preparation of Courses and Materials by Program Type

Program Type	Listed 1-2	Listed 3-4	Listed 5-8	Not Used	No Answer
Fundamentals (5)*		1		3	1
Recognition (14)*	4	3	2	3	2
Problem-Solving (14)*	7	1	2	2	2
Empowerment (7)*	5		1	1	

*Number of organizations in each category.

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Appendix D

Role in Right-To-Know Campaign

Question 7 of the INFORM survey asked:

"Have you played any role in a right-to-know campaign?"

__________YES __________NO

If YES, please describe.

The chart below presents the distribution of responses to question 7 by program type.

Role In Right-To-Know Campaign

PROGRAM TYPE	YES	NO	NO ANSWER
Fundamentals (5)*		5	
Recognition (14)*	7	5	2
Problem-Solving (14)*	10	2	2
Empowerment (7)*	7		

*Number of organizations in each category.

No precise interpretation of the "NO" answer is possible. It may mean that there is no right-to-know campaign in the respondent's area; or that the respondent does not (or has not) participated in a campaign that is taking place (or has taken place).

Appendix E

Affiliations with other Groups and/or Institutions

Question 19 of the INFORM survey asked the participants:

"Please enter below the names of the most important or representative groups or institutions with which you are affiliated or with which you cooperate in safety and health education and training activities. Indicate also the nature of your cooperation and affiliation."

The question then lists 11 categories to respond to. They are: Union Locals; Union Internationals; Business Firms or Trade Associations; COSH Groups; Universities and Colleges; Medical Centers, Hospitals, and Clinics; Environmental and Citizen Groups; Women's Organizations; Minority Organizations; Local or State Government Agencies; and Other.

The chart below indicates the number of different kinds of groups with which survey respondents are affiliated.

Number of Different Kinds of Groups and/or Institutions With Which Programs are Affiliated, by Program Type

PROGRAM TYPE	1-3 kinds of groups and/or institutions	4-5 kinds of groups and/or institutions	6-7 kinds of groups and/or institutions	8-10 kinds of groups and/or institutions	No Answer
Fundamentals (5)*	5				
Recognition (14)*	2	6	3	2	1
Problem-Solving (14)*	1	3	5	5	1
Empowerment (7)*		2	1	3	1

*Number of organizations in each category.

Case Study of
a Program Developed by Local 199,
UAW, and General Motors of Canada

Part of an INFORM Report
on Worker Education and Training Programs
in Occupational Safety and Health

Prepared for
U.S. Congress,
Office of Technology Assessment

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Case Study of a Program Developed by Local 199, UAW, and General Motors of Canada

This case study reports on the occupational health and safety education program that has been jointly developed and conducted in St. Catharines, Ontario, by the United Automobile Workers, Local 199 and General Motors of Canada. The information used in this report was obtained from conversations with UAW-officials, GM representatives, apprentice instructors, and workers who have completed the program, as well as from written materials provided by Local 199, the Ontario Federation of Labor (OFL) and GM.

According to Local 199 and GM, the program's objectives are: 1) to increase worker awareness of occupational health and safety hazards on the job; 2) to increase worker awareness of their rights and responsibilities under the law and contractual provisions; 3) to encourage labor and management to work together to prevent accidents and illnesses.

The St. Catharines program is a Recognition Program. It provides the workers with the skills and information needed to identify unsafe machinery and unhealthy conditions and encourages them to report these observations to management.

This kind of program, according to Frank Mirer, Director of Health and Safety for the UAW International, is the educational goal of the International's Health and Safety Department. He considers the St. Catharines program more advanced than most of the training programs of the U.S. automobile industry, in terms of the amount of materials jointly-developed, and the degree of cooperation in conducting the program.

General Motors also appears to regard the program as effective enough to recommend its expansion. Edward Hodge, Director of Labor Relations at General Motors of Canada, commended the jointly-conducted apprentice program in a letter dated August 4, 1982: "Clearly, the success of this program should encourage all of us to expedite safety training for journeymen as well." (see Appendix A)

The cooperative St. Catharines program includes three courses: a 30-hour committeemen program, an 80-hour apprentice program and a 40-hour journeymen program. As of the summer of 1983, all 35 committeemen and 200 apprentices in the St. Catharines plants had completed their courses. In the fall of 1983, the course begins for all 1,700 journeymen, and 63 new apprentices will begin the apprentice instruction in August 1983. By 1985 it is expected that 2,007 of the 6,000 workers in the St. Catharines plants as well as the skilled trades supervisors and general supervisors in these plants will have gone through these cooperative and comprehensive courses.

MATERIALS AND METHODS

Don Adams, Local 199's health and safety representative, and the GM health and safety representative, teach 28 different course topics about general occupational health and safety issues, and about conditions and machinery found specifically in the three St. Catharines plants.

These subjects are designed to address the needs of electrical workers, pipe fitters, machinery repairers, tool makers, millwrights and pattern makers. Among the course topics: Hazard Recognition, Ergonomics, Communication, Principles of Control, Advanced Rigging, Trade Specifics, GM Suggestion Plan and Legislation. (see Appendix B)

Although the three courses use many of the same materials, they differ in emphasis and scope. The 80-hour apprentice course focuses on both occupational health and occupational safety. Much of the safety instruction is very basic -- such as pointing out consequences of not cleaning up after completing the job. The 40-hour journeymen course does not include the basic safety instruction used in the apprentice course and places most emphasis on recognizing hazards. The 30-hour committeemen training program is designed to help committeemen carry out plant inspections in an effective manner.

The courses are held at the union hall during the day and on company time. Instruction lasts five days, eight hours a day, with two or three subjects discussed daily. The longer apprentice program is divided into two parts, and is taught at different times in the year. The classes are led by the two health and safety representatives and they are assisted by two tradesmen trained as instructors. (see Appendix C)

The overall aim of the program is to teach workers to recognize hazards. After completing the program, the worker is expected not only to work in a safer manner, but also to assist management by identifying and reporting hazards. This emphasis on hazard recognition is based on the underlying assumption of the program: the majority of accidents and illnesses result from hazards inherent in the labor process and workplace conditions, rather than from workers' carelessness and negligence.

Specifically, according to GM and the Local, the workers are taught to:

- identify safety hazards -- such as improperly guarded machines, and hazards associated with conveyors, slings, and trucks;
- identify health hazards -- such as carcinogens, and the health effects of noise and stress;
- understand terminology associated with hazards;

- use and read monitoring equipment;
- recognize symptoms of exposure to different substances, and understand their health effects;
- identify the different hazard control methods -- such as substance substitution, engineering controls, safety devices and personal protective equipment;
- understand principles of each control method, and evaluate each one's strengths and weaknesses;
- understand and use their rights under the law and contractual provisions -- such as right-of-access to information about chemicals on the workfloor, and right-to-refuse unsafe work;
- understand worker and company responsibilities under the law and contractual provisions, placing emphasis on workers' responsibility of reporting hazards;
- use available communication mechanisms to report observations, suggestions, and complaints to management -- such as registering complaints to the union inspectors and supervisors or at safety meetings. (see Appendix D)

The three means by which this information is conveyed to the workers:

1) Films -- such as "60 minute news" reports on toxic substances and cancer -- to dramatize the hazards and risks inherent in the workers' jobs;
2) Lectures aimed at developing identification, monitoring and communication skills;
3) Discussions in class and in subgroups about information given in films and presentations and how these are relevant to the working environment in St. Catharines.

Participation of workers in classes is an important element of the courses. It is considered effective by Don Adams in internalizing knowledge and stimulating the students to generate questions and ideas. During discussions the workers are asked to relate their observations and experiences in the workplace. For example, during a discussion about accident prevention, one apprentice told a story about a woman he saw lose her hand because she improperly handled a machine. Since then, he said, he has been much more careful when operating machinery.

In a particular exercise, the workers used their experience to establish a list of proper techniques to handle specific plant machinery. This exercise not only formulated a comprehensive checklist for the workers but also provided the instructors with information for future courses.

MEASURES OF EFFECTIVENESS

The effectiveness of the St. Catharines cooperative program is evident in the observation and actions of both management and the workforce.

One obvious measure of success is the increasing number of GM workers exposed to instruction. The number of workers provided instruction in the St. Catharines program grew from the initial 35 committeemen, to 200 apprentices in 1982 and will include, starting in the fall of 1983, 1,700 journeymen. But even more convincing is the fact that recently General Motors extended instruction to all of the 5,000 journeymen that work for the company in Ontario. The inclusion of all of these journeyman will cost GM millions of dollars in off-the-job wages, since journeymen continue to be paid while participating in the course.

The apprentices have overwhelmingly approved of management's and labor's cooperative efforts in the course. After completing the first 40 hours of training, 146 (out of 200) apprentices filled our a course evaluation, and 143 of them reported that they felt management and labor were sincere in their efforts to work together in the course. All of the 146 agreed the cooperative approach is an effective way to eliminate hazards. (see Appendix B)

All 146 apprentices also reported they were more aware of occupational health and safety hazards and issues. These hazards and issues include toxic substances, carcinogens, noise, legislation and machine safety. For example, one apprentice stated that, before the course, he did not even know the company had a chemical-identification policy, and after the course he knows how to get this information.

More workers are now observed by the health and safety representatives to be performing their jobs in a proper and/or safer fashion. According to Don Adams, the committeemen are finally using all of their inspection time to inspect, and more apprentices are following prescribed safe-work procedures, such as locking up their machines when engaging in other tasks -- a procedure journeymen tend to avoid. Furthermore, Don Adams and others interviewed report that the apprentices are now asking "substantially" more questions and are offering "substantially" more suggestions and observations.

Some workers have used knowledge of the law and company procedure to prevent disaster. In one example, a committeeman was approached by a worker who had a question about a substance. The committeeman, following proper procedure, checked to see if the chemical was on the list of permissable substances and, finding it was not, told the worker to refuse to use it. It turned out that the substance was not at all the right one for the job and could have caused a serious health problem had it been used.

A final measure of success is that many of the supervisors are now requesting to take the program. Their interest in the program was a primary consideration in GM's recent decision to extend instruction to the supervisors in the St. Catharines plants. According to GM, supervisors are reporting that workers are now pointing to hazards that they themselves should be recognizing. One instructor observed that the workers' questions have challenged supervisors to generate responses, which in turn have generated more questions. He concludes that this process should lead to a more healthful and safer workplace.

LABOR-MANAGEMENT COOPERATION

Labor and management have cooperated in the development of the program. Information comes from both sources. Labor's primary contribution is through the Ontario Federation of Labor (OFL), located in Toronto, Ontario. The OFL has a health and safety training program that has been adopted by 16 business organizations, including Ford of Canada and Chrysler of Canada. The program has been used by the unions, independent of business training programs, to reach over 3,000 workers in the last three years. (see Appendix F)

Local 199 and GM incorporated the OFL class structure and OFL materials into three courses. The committeemen's course is entirely composed of the OFL program. This program accounts for 90 per cent of the materials used in the first 40 hours of the apprentice course, and for 75 per cent of the journeymen's course.

Managment's primary contribution to this joint effort is through a business organization, the Industrial Accident Prevention Association (IAPA), which has provided 16 hours of basic safety instruction. This material, which is used primarily in the second part of the apprentice program, stresses the importance of following prescribed safety procedures and using proper work techniques and clothing. In addition, the Construction Safety Association in Ontario provided films on accident prevention.

The IAPA material is used predominantly in the apprentice course. In the initial apprentice course (1982-83), this material was presented during the second part of the course, and was taught to all the apprentices. Beginning in the summer of 1983, however, IAPA instruction will only be furnished to apprentices with no experience in the automobile industry, and will be taught during the first 40 hours of the program.

The UAW and GM health and safety representatives worked together and developed supplemental materials. These materials linked the more general materials of the OFL and IAPA to workplace examples that are easily understood by the students. In one instance, an audio-visual presentation of the different machines in the plants was developed to supplement a discussion on proper machine handling.

Labor and management also cooperate in the classroom. The health and safety representatives of the union and GM alternate as instructors on a weekly basis. Also, during the class on toxic substances, a representative of the GM plant Committee on Hazardous Materials presents the company's toxic substance policy to the class. The balance of the class time is spent presenting and discussing information about the selected topics. According to workers interviewed by INFORM, and according to results of course evaluations (see above, page 4) management and union positions on different occupational health and safety issues are presented fairly and in a non-biased fashion.

The program encourages the worker to work with management outside the classroom to identify and eliminate hazards. In a few cases, the local and GM have not been able to agree on a solution to a problem. For example, some workers feel that a certain smell from the coolant used in large transfer equipment may be harmful and they have asked management to take action. According to the union, management still has not satisfactorily responded to this request. However, in most cases, the local and GM have been successful at working together and solving problems at the plant level.

The workers are encouraged by both GM and the Local to bring their suggestions and observations to the attention of union committeemen, their supervisors, or the plant health and safety representatives. The courses emphasize the importance of identifying hazards, but not in an adversarial manner, according to Don Adams. He reports that instruction in the committeemen program stresses that inspections are meant to help the company identify hazards and should not be used to gather information to fuel labor-management disputes.

BACKGROUND

Prior to this cooperative program, GM of Canada provided its St. Catharines workers with only piece-meal training which consisted of passing out literature and holding a monthly safety meeting. But Don Adams, Local 199's health and safety representative, wanted comprehensive health and safety training for the workers, and especially for union committeemen who are responsible for inspecting the workplace. In the spring of 1981 he completed the OFL program which he brought to the attention of the GM Plant Manager and Director of Labor Relations, and requested that it be approved for committeemen training. GM's management was impressed with the OFL materials and approved the 30-hour course in September 1981. Later that fall, the program was administered.

After completion of the committeemen course, Don Adams and his GM counterpart agreed that the OFL program, plus other materials developed by management sources, should be used for a jointly-conducted apprentice program. This proposed course would satisfy a 1979 GM-UAW contractual agreement for 80 hours of jointly-developed apprentice training.

The proposal was presented to the Apprentice Committee and the Joint GM-UAW Skilled Trades Committee. Don Adams spent much time developing the apprentice course and negotiating with the GM representatives for their approval. The two committees approved the first 40 hours of apprentice training in November 1981 and the second 40 hours in November 1982.

According to the 1979 GM-UAW agreement, once 80 hours of apprentice training is successfully completed, a joint program for journeymen would be agreed upon. Thus, in January 1983, the Joint Master Trades Committee and the Health and Safety Master Committee, which included Don Adams, agreed to incorporate much of the materials used in the apprentice course into the journeymen's course. Since the committee's agreement, Don Adams and his GM counterpart have been organizing the 40 hours of journeymen instruction. The course is scheduled to begin in the fall of 1983.

Case Study of a Program Developed
by Local 201, International Union
# of Electronic, Electrical, Technical, Salaried and Machine Workers

Part of an INFORM Report
on Worker Education and Training Programs
in Occupational Safety and Health

Prepared for
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Case Study of a Program Developed by Local 201, International Union of Electronic, Electrical, Technical, Salaried and Machine Workers

Worksite inspections of suspected hazards, as requested by members, are the key to the effective worker education and training programs in safety and health conducted by Local 201 of the International Union of Electronic, Electrical, Technical, Salaried and Machine Workers (IUE), of Lynn, Massachusetts. From February 1980 to May 1983, Local 201 has conducted more than 140 inspections in five General Electric (GE) plants located north of Boston, where it represents 8,500 machinists, sheetmetal workers, welders, press operators, assembly workers, clerical workers and others employed in the production of jet engines, steam turbines, and electronic aircraft instruments.

The major hazards encountered by Local 201 workers are exposures to cutting oils, metal dusts and solvents. For example, methylene chloride is a highly volatile industrial solvent that, according to the company's Material Safety Data Sheet for the chemical, can cause "loss of coordination and equilibrium and, if exposure is prolonged, unconsciousness and even death." Other hazards present in the plants include metal fumes, asbestos, noise, poor ventilation, heat stress, epoxies, formaldehyde, cyanide, PCBs and video display terminals.

Local 201 conducts a Problem Solving program of worker education and training. The union's professional industrial hygienist uses regular inspections to teach workers to take an active role in reporting, analyzing, and helping to solve problems of hazard identification and control.

A major indication of the program's effectiveness is a union vote in March 1983 that approved, by a 2-to-1 margin, a 10-cent a week increase in union dues to cover the costs of continuing the program at the termination of five years of federal funding under the New Directions program of the Occupational Safety and Health Administration (OSHA). Federal funding is due to end in the fall of 1983.

Information for this report comes primarily from interviews with local 201's current industrial hygienist, Richard Youngstrom; and with members of the union's Health and Safety Committee, and union workers. Also interviewed were members of Massachusetts Fair Share who use Youngstrom as a technical consultant for their program of community inspections of hazardous worksites. Other sources of information include Local 201's files on plant inspections, union literature, and newspaper articles appearing in non-union publications.

INFORM tried, on several occasions, to arrange for interviews with representatives of General Electric management, but GE showed no interest in giving INFORM information or opinions about the effectiveness of local 201's program of worker education and training.

Classrooms on the Shop Floor

On the average of once a week, the industrial hygienist employed by Local 201 is requested to visit a plant area or job to examine a suspected hazard. During the inspection he educates and trains workers by:

- distributing literature about the nature of the hazard(s) investigated;
- interviewing workers about symptoms of exposure, signs of stress, and other complaints;
- demonstrate and/or explain methods of measuring the environment;
- demonstrate and/or explain methods of measuring body uptake;
- explaining safety and health standards set by the Federal Occupational Safety and Health (OSHA) and recommendations for standards published by the National Institute for Occupational Safety and Health (NIOSH);
- demonstrating methods of measuring contamination levels and collecting other quantifiable evidence of the problem;
- teaching workers what questions to ask and what steps to take to identify hazards on future occasions;
- actively involving company health and safety officials in discussions with workers.

Case histories of inspections provide Local 201 with first-hand accounts of shop hazards for use in the union's semi-annual courses in safety and health, in workshops, and in steward-training programs. Enrollment in the courses last year was 75. The total number of workers trained in courses, workshops, and steward-training programs since 1978 is 200. Inspections also help the union target needs for new information and instruction to keep pace with changing workplace conditions such as, for example, the recent introduction of video display terminals.

Scheduling and Conducting Inspections

Inspections are scheduled in response to written requests, brought to Local 201's Health and Safety Committee by either workers or union officials. (see Appendix B) Local 201's business agent contacts GE management with information about the problem, such as the place, the shift and the nature of the suspected hazard, and an inspection date is set. In the case of an emergency, an inspection can be done immediately, but the usual lag between complaint and inspection is one week.

Inspections are currently conducted by Richard Youngstrom, Local 201's certified industrial hygienist. Until April 1982, Local 201 had a second industrial hygienist, Richard Weeks, who also conducted inspections. Accompanying the union's industrial hygienist are an industrial hygienist from the company, a company representative (such as a person from the labor relations department or a foreman), and a union representative from the Health and Safety Committee or the executive board.

During a typical inspection, Youngstrom takes appropriate measurements and makes professional observations. As a former OSHA inspector, he is also on the lookout for OSHA violations, but this is not the major focus or importance of 201's inspections. As Youngstrom states it, "OSHA inspections are conducted to find violation of standards; Local 201 conducts inspections to identify problems." In fact, most union inspections are prompted by workers complaints of hazardous conditions that are not covered by federal or state laws, or involve exposures lower than OSHA standards.

The following examples of inspections come from one of the 15 buildings at the GE Riverworks site, over a two year period:

- investigation of blood-lead levels of workers exposed to bronze in the packing ring area;
- investigation of safety hazards in the punch press area;
- coolant analysis of some machines in the screw products area;
- testing for excessive heat in the stellite welding room;
- inspection of fumes in the dye-pen area and design of a better ventilation system;
- removal of asbestos wrapping on pipes in the warehouse area.

As mentioned before, Youngstrom educates workers on the shop floor by distributing literature and conducting interviews. Both the discussion and the materials emphasize the general process of hazard recognition.

The company's industrial hygienist often takes an active part in the shop-floor discussions. In contrast to the generally contentious relations that exist between the company and the union, these inspections provide regular opportunities for limited, specific management-labor cooperation in the analysis of job problems and the search for solutions.

Follow-up

After the inspection, Youngstrom writes a report and outlines recommendations that address the problem investigated. Past recommendations have suggested many changes: specific engineering controls, substance alterations, personal protective equipment, product improvement, better housekeeping, medical tests, changes in the work assignments (e.g. not working alone), job transfers, and better education of workers. (see Appendices A and C)

Inspection reports and recommendations are sent to union representatives and to interested workers. Local 201 has no power to enforce its recommendations, but in the majority of cases its recommendations have eventually been adopted by management -- though the time it takes for such results may be considerable. (see Appendix A, No. 1) If an inspection uncovers violation of an OSHA standard (which happens about 10 percent of the time) the threat of an OSHA inspection is sometimes needed to spur the company to action. In general, however, Local 201 prefers informal negotiations with management as a means of convincing the company to take action. This method gets results faster, builds confidence in the union, and is not bound by the constraints of outside agencies.

Results

The effectiveness of Local 201's inspection-focused program of worker education and training is indicated by the following:

- the steady pace and total number of inspections: over 140 in a three-year period, almost one inspection a week;
- the proportion of inspections requested by individual workers: about 65 percent of the total;

- the number of union workers - 3,500 - involved in the inspections and affected by the recommendations over a three-year period;

- the 500 documented worker requests -- requests that take more than one hour to fulfill -- for technical information and advice from the industrial hygienist concerning conditions affecting 6,000 workers, over a three-year period;

- the 2-to-1 union vote (in March 1983) to increase dues by 10 cents a week to finance the Local 201 safety and health program beginning in the fall of 1983, at the termination of five years of New Directions grant support (see Appendices D and E);

- the growing responsiveness of GE management to worker complaints and union recommendations. A majority of Local 201's recommendations are eventually adopted by the company, and during the past three years, the speed of the response has increased, as for example in the asbestos incident described in Appendix A, No. 5. (See all of Appendix A, "Inspections that Produced Results");

- the number of inspections done for other unions (12) and community organizations (10). Local 201's industrial hygienist aids these groups in conducting inspections of hazardous worksites. (See Appendix F for Youngstrom's report on a Neighborhood Inspection of Geochem, Inc., conducted by Massachusetts Fair Share.)

Reasons for Success

Two major reasons for the effectiveness of Local 201's program are federal funding and a very strong union organization.

Since 1979, Local 201's safety and health program has been primarily funded by grants from the New Directions program of the Federal Occupational Safety and Health Administration. The amounts of the yearly federal grants from 1979-83 have been $50,000, $75,000, $82,500, $75,000, and $40,000. The total is $332,500 for the five-year period. The program also receives in-kind support from the Local, which, if translated into monetary terms, has been around $10,000 per year.

Local 201 is a stronger organization than most union locals. It has 14 full-time union representatives, including a president, a vice president, a business agent, an assistant business manager and 10 executive board members.

History

Local 201 won the right to inspect plants in 1980. This brought major new opportunities for education and action to Local 201's safety and health program whose 12-year history from 1968-80 can be briefly summarized as follows:

1968 Local 201's safety and health activities began with the publication of union newspaper articles.

1972 A seven-member union safety and health committee was founded and began weekly meetings. (Membership was later expanded to nine). The committee has never been recognized by management, but received technical assistance from groups such as Urban Planning Aid, and the Massachusetts Coalition for Occupational Safety and Health.

1978 The OSHA New Directions program began its five years of support for Local 201's safety and health activities with a grant of $50,000. Two industrial hygienists, Jim Weeks, and Richard Youngstrom, were hired to run the program. Safety and health activities increased markedly. A 15-week course of formal education and training was offered, and technical assistance in chemicals identification and medical referrals was provided, to union members.

1979 In the aftermath of a major methylene chloride spill, and OSHA inspections that uncovered four "serious" violations of agency regulations, Local 201 and GE reached an informal agreement on a long list of union demands. These included 1) detailed inspection and maintenance procedure for the vapor degreaser; 2) additional training for company medical personnel in recognizing symptoms of methylene chloride poisoning; and, 3) the installation of a continuous monitor to measure concentrations of methylene chloride in the air.

Two major reasons for the far-reaching agreement were the effectiveness of OSHA policies in promoting labor-management negotiation, and the professional competence of the local's safety and health program.

However, the new 15-week course in worker education and training fell short of its goals. The two industrial hygienists of Local 201 responsible for the course, concluded that formal classroom training was an inadequate method of preparing workers to solve problems on the job. Detailed information about hazards likely to occur on jobs, did not prepare workers to identify and analyze the unique components of actual problems, nor did it equip them to help tailor appropriate solutions.

1980 GE agreed to allow Local 201 to enter plants to investigate worker complaints of safety and health problems. The agreement was part of an out-of-court settlement of an unfair-labor-practices case brought by Local 201 against GE for the latter's refusal to allow the union to visit the shop floor to collect data about air contaminants and noise levels needed to verify a GE report. The agreement stated that the company would give...

> "qualified industrial hygienists, chosen by the union, access to its plants under reasonable conditions in order to make observations and studies related to employee grievances which are being processed or being evaluated for submission." (Appendix G)

Conclusion: Local 201's Program is a Strategy for Change

Educating and training the workers of Local 201 is part of a strategy for change that centers on the use of inspections. This strategy has the following elements:

- focus attention of management and labor on particular hazards on the shop floor;
- investigate specific problems, on a continuing basis, as part of plant routine for both workers and management;
- collect quantitative evidence of problems wherever possible;
- identify specific methods available to both management and labor to improve conditions and better protect workers;
- use informal meetings between management and labor as much as possible to seek solutions to workplace problems; use formal methods such as grievance procedures and CSHA complaints only when informal methods are unavailable or ineffective.

APPENDIX A

Inspections That Produced Results

The following are five examples of safety and health inspections conducted by Local 201's industrial hygienists in General Electric plants located north of Boston, between 1980 and 1982. They illustrate both the nature of the job hazards Local 201 members face, and the positive results of Local 201's inspection program. Information comes from Local 201's files.

1. NITRIC, ACETIC, AND HYDROFLUORIC ACIDS (1980).

Workers in an experimental descaling operation complained of nose and throat irritation and strong odors. An inspection of the worksite documented hazardous exposure levels to the acids. When the company failed to act on recommendations, the union safety and health committee requested an OSHA inspection that revealed one "serious" and ten other violations. GE immediately took the tank causing the problem out of operation. Later, an agreement between the Department of Labor and GE (the union requested party status and participated in the meetings in the OSHA office) resulted in a GE commitment to take a series of measures to protect workers when the tanks returned to service. These measures included 1) providing workers with information concerning the effects of inhaling the acid fumes; 2) providing workers with protective equipment; and 3) keeping the area around the eyewash and deluge shower free of obstruction. Fifteen months elapsed between the first worker complaints and the agreement between GE and the Department of Labor.

2. HEAT (1981).

Stellite welders concerned about their inability to conceive children requested an inspection by the union's industrial hygienist. The welders' job involved straddling the part being welded, with their groins about eight to ten inches from metal heated to 600 degrees Fahrenheit. Youngstrom, familiar with research findings showing that testicle temperatures elevated by as little as four degrees Fahrenheit will stop sperm production, recommended that workers wear aluminized aprons. At Youngstrom's suggestion, GE provided the aprons and, though no systematic follow-up has taken place, workers' complaints stopped.

3. NOISE (1981).

Several Local 201 inspections of workers' complaints about noise levels documented exposures in violation of OSHA standards. The problem was serious and the solution recommended by Youngstrom required large company expenditures. Instead of calling for an OSHA inspection, the union asked for a special management-labor meeting that resulted in agreement on protective measures that could be taken immediately and relatively inexpensively. The meeting also produced agreement on a plan for a more permanent (and more expensive) long-term solution.

4. FORMALDEHYDE AND CARBON MONOXIDE (1982).

In a plant that builds steam turbines, 135 workers complained of eye, nose and throat irritation. Although the union's industrial hygienist suspected that the problem was formaldehyde exposure from incomplete combustion in the gas-fired, heat treated lathes, his first two inspections occurred when the ovens were not in use, and therefore produced no evidence of exposures. A third inspection occurred 45 minutes after the complaints were received and produced evidence of 4-7 ppm (parts per million) formaldehyde concentration and 200-300 ppm carbon monoxide concentration above the lathes. These concentration levels were in violation of OSHA's standards for formaldehyde and carbon monoxide, which were 3 ppm and 50 ppm, respectively. The company shut the ovens down and called in an outside service to clean and calibrate the fuel jets. The company instituted regular maintenance procedures that now keep the problem from recurring.

5. ASBESTOS (1982).

In the same plant where the formaldehyde incident occurred, steam pipe condensation knocked down asbestos pipe lagging. When workers refused to work, Youngstrom made an inspection and the company reacted immediately by blocking off the area, ordering the pipes to be relagged with non-asbestos lining, and testing the air for asbestos contamination.

Case Study of
a Program Developed for Management
by the International Lead Zinc Research Organization

Part of an INFORM Report
on Worker Education and Training Programs
in Occupational Safety and Health

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Case Study of a Program Developed for Management by the International Lead Zinc Research Organization

This is a case study of how the Environmental Health Department of the International Lead Zinc Research Organization (ILZRO) assists its thirty-three member companies and small businesses in developing worker training programs on the hazards of lead.

ILZRO assists these companies in three ways: it develops materials for use in their training programs; it teaches supervisors and other management personnel in the principles and methods of instruction; it supplies technical expertise, particularly to small businesses.

Information used in this report comes from conversations and written materials primarily provided by Neil Maresca, Training Coordinator for ILZRO. Owing to time and financial constraints, INFORM was unable to visit either of the two member companies, St. Joe Lead Company and Ethyl Corporation, that are used as examples in this report. Information about these companies was obtained in phone conversations with company representatives and ILZRO's Lead Environmental Health Newsletter.

ILZRO's activities are designed to help companies meet the requirements of the lead standard set by the Occupational Safety and Health Administration. This standard was issued in 1978 and put into effect in 1980. It applies to companies whose employees are exposed to more than 30 micrograms of lead per cubic meter of air in an eight-hour period. The standard, among other things, requires such companies to:

1) establish an air monitoring program;

2) provide medical surveillance (physical examinations and blood-lead tests) of any worker exposed to air-lead concentrations above the standard for 30 or more days per year;

3) provide a training program for employees that must inform workers about the symptoms and effects of lead exposure, and about the company's and their rights and responsibilities under the medical surveillance program and also under the "medical removal protection procedure."

This procedure requires that workers be temporarily removed from an area of heavy exposure to lead if their blood-lead concentrations are too high.

EDUCATIONAL APPROACH

ILZRO's program is an example of a Fundamentals program. Workers are instructed, by ILZRO-trained supervisors and managers, to follow prescribed work procedures, correctly use respirators, and adopt proper personal hygiene. ILZRO's instruction also emphasizes the importance of worker participation in company-administered medical surveillance programs.

Although ILZRO offers a Fundamentals program, it strongly urges member companies to conduct other types of programs, using ILZRO's materials. For example, St. Joe Lead Company, (discussed below) conducts worker training in ways that resemble the Recognition model more strongly than the Fundamentals model.

ILZRO uses a top-down educational approach. It focuses its activities on supervisors and other management personnel. It does not involve itself with union-initiated training programs and joint labor-management health and safety committees. According to Neil Maresca, this ILZRO policy is aimed at avoiding any contact with unions or workers that would interfere with the supervisors' direct communication with workers. This, he believes, fosters unity between all levels of management. Also, he reports that this management-oriented approach is intended to demonstrate to the workers the company's concern for their health and safety.

ILZRO emphasizes the importance of communication between management and labor. The ILZRO booklet entitled, Improving Employee Health Through Management-Labor Cooperation, described the communication process as essentially being an "influence process", i.e. the ability to elicit a desired response. This booklet is used in conferences, workshops and speeches on the subject.

The objective of the instruction booklet is to teach the manager "to choose the appropriate communication pattern for dealing with the specific problem and people involved." It discusses several models of communication. One such model is the Controlling Approach, where the manager "pressures" subordinates into doing something he feels should be done. A second pattern is the Relinquished Approach, in which the manager gives up some influence over a situation. A third model is the Developmental Pattern, where influence flows back and forth between managers, supervisors and workers.

ILZRO, in its conferences, workshops and speeches, emphasizes the importance of the Developmental model. According to Neil Maresca, this communication approach is an effective way to enlist worker participation in controlling the hazards of lead.

MATERIALS AND ACTIVITIES

Handbooks

The primary device used by ILZRO in its training and education programs has been the Employee Guide to the OSHA Standard for lead and its accompanying instructor's manual. In the past two years, 2,000 copies of this guide were distributed. The guide is well-designed and all information, including the details of OSHA lead limits for both the blood and the atmosphere of the workplace, is presented in a clear and straightforward style. The handbook includes information on the symptoms of lead exposure, air monitoring, use of respirators and personal hygiene.

The instructor's manual that accompanies the Employee Guide points out that supervisors must be careful in presenting the materials: "The greatest challenge you will face in presenting this material will be striking a balance between OSHA's requirement that the workers understand the effects of lead intoxification while at the same time avoiding overstatement and emotion."

ILZRO is also in the process of putting together two new handbooks. The first of these has been approved by OSHA and was scheduled to be released by June 30 of this year, and is to be entitled, The Small Businessmen's Guide to OSHA Lead Standard.

The second of the new manuals, the Occupational Health Handbook for Lead, is being written and as of the Spring of 1983 has not been reviewed by OSHA. Plans are to have this handbook out by the end of the current grant year, April 30, 1984.

Other printed materials

ILZRO also publishes, at irregular intervals, a newsletter, The Lead Environmental Health Newsletter, with a circulation of about 1,000 copies. This newsletter is sent to over 200 firms and 300 plants. Other printed materials produced include: a workbook on communication skills in labor-management teams (cited above), an annual digest of research on lead, and several checklists on lead control and the OSHA regulations for use at ILZRO workshops.

Audio visual materials

ILZRO also has developed audio-visual materials for health and safety training. These include slide-tape shows and films. The primary audio-visual contribution is a 5-part slide/tape program, Lead and Your Health.

The slide programs are made so that they may be used by any company in the lead industry. However, future plans include the production of videotapes and films produced at, and directed towards, specific corporations and plants.

Conferences and workshops

ILZRO directly trains its member companies through conferences and workshops, with some additional work done in the form of training sessions tailored to specific companies. This year, five conferences are scheduled to be held in hotels in Philadelphia, Tampa, Chicago, Houston, and Los Angeles. These conferences are expected to involve approximately 30-35 people each, including managers ranging from vice-presidents to foremen. Last year, approximately 100 representatives from 50 companies and 80 plants took part in three such conferences.

Training workshops are set up to suit participants' particular needs. Four of these workshops were held in 1982, ranging in size from 14 to 125 supervisors. Last year over 200 supervisors attended. Two of these workshops discussed "Lead/Health Awareness", while the other two focused on "Management/Labor Teams" and "Lead Control in the Workplace." All but one of the workshops took place on companies' properties. The one held off company grounds was directed at small businessmen and was held at a trade association meeting.

ILZRO also supplies expert technical assistance to companies too small to have their own health and safety staff. For the most part, this help is provided over the telephone. ILZRO advises businesses about their responsibilities under the lead standard, the health effects of lead, and control methodologies to curtail exposures and/or reduce blood-lead levels in their workers.

Another method used to reach small business is the dissemination of information at trade association conferences. ILZRO had booths at three such conferences last year:

1) the Independent Battery Manufacturer's Association;

2) the National Automotive Service Repair Association; and

3) the American Ceramic Society exposition.

ILZRO reports that this has been an effective means of reaching small business. Maresca reports that hundreds of copies of training booklets, OSHA Lead Standard guides, and ILZRO newsletters have reached individuals to whom this information would not otherwise have been available.

Measures of Effectiveness

The effectiveness of the ILZRO program can be assessed in terms of materials used, assistance rendered, and reductions in lead concentrations in workers' blood. Last year, the ILZRO program directly reached the following numbers of supervisors and managers in the lead industry.

Activity and Materials	Supervisors and/or Managers Reached
Newsletter	1000
Slides, Filmstrips, Video Tapes	200
Workshops, Conferences, Speeches	200
Consulting	30

Although it is impossible to determine the exact number of workers instructed by supervisors influenced by ILZRO, Neil Maresca estimates that indirectly thousands of workers have been reached through these materials and activities.

It is impossible to directly link the ILZRO education and training program to reductions in blood-lead levels. Industry-wide statistics show a dramatic drop in the percentage of workers who had a lead concentration of 60 or more micrograms of lead per 100 grams of blood between 1978 and 1982 (see Table 1).

Table 1

The percentage of workers having blood exceeding the OSHA limit of 60 micrograms lead per 100 grams of blood:

	Primary Sector Workers	Secondary Sector Workers	Battery Sector Workers
1978	30	40	30
1982	4.5	4.5	6

Neil Maresca states, "certainly education and our health and safety program have played a role in reducing blood-lead levels."

MODEL PROGRAMS

St. Joe Lead Company

The industry-wide programs in health and safety assisted by ILZRO grew, to a large extent, out of a pilot program sponsored by the Lead Industry Association at the St. Joe Lead Company smelter in Missouri. The success of St. Joe's program since it began in 1980 has provided an industry-wide incentive for similar company programs in safety and health.

The most important part of the St. Joe program is the Problem Solving Work Group (PSWG). This is a group of one or two managers, one or two supervisors and all employees who wish to attend - normally 8 to 10 workers per meeting. According to an article in ILZRO's Lead-Environmental Health Newsletter, "St. Joe Lead Company reports that they are very satisfied with the results of the Problem Solving Work Groups in lowering blood leads and increasing morale."

A PSWG is led by a supervisor who guides the group through the problem-solving process. According to the ILZRO newsletter, this process proceeds in the following manner:

- problem identification (most often problems emanate from the group members);
- clarification through discussion;
- suggestions and evaluations of alternative solutions;
- implementation of recommendations (this is the responsibility of the discussion leader).

The St. Joe program has both Fundamental and Recognition characteristics. The workers who participate in these PSWGs not only are instructed about proper work techniques, but are also able to ask questions and offer solutions. ILZRO's newsletter suggests this program has helped workers understand the reasons for company health positions, and the importance of adopting prescribed health procedures.

Involvement in these PSWG programs of St. Joe is completely voluntary for both supervisory personnel and hourly employees. Supervisors who are interested in setting up such work groups take a two-day training session with an outside consulting firm (P. Dolan and Associates) in the principles of motivation and theory of group dynamics and communication.

The ILZRO newsletter reports the level of involvement among the plant's 785 hourly employees is about 15 per cent. However, since all participants do not attend all meetings, any given meeting would have about 10 per cent worker representation.

St. Joe has reported that from October 1980 through May 1982 there was an 87 per cent reduction in the number of its workers whose blood-lead levels exceeded 60 micrograms of lead per 100 grams of blood, and a 34 per cent drop in absenteeism. The company says it is very difficult to directly attribute these reductions to the PSWGs, but thinks the problem-solving groups are at least partially responsible for them.

Ethyl Corporation

Another model program under the auspices of ILZRO is conducted by the Ethyl Corporation at its Baton Rouge, Louisiana lead alkyl production plant. This program is designed to reach the plant's 550 hourly employees through their foremen. The Lead Environmental Health Newsletter identifies the foremen as being essential to the success of the training program. Foremen are responsible for motivating their workers and monitoring the workplace.

In a one year period, foremen were given 12 monthly courses in "Industrial Hygiene and Health Aspects of Occupational Lead Exposure." These courses were taught by the company hygienist. Once the foremen are trained, both they and the medical staff identify which of the blood-lead concentrations in the plant's 550 workers are above accepted levels. These are the employees who are targeted for training.

Ethyl's program also involves twice monthly meetings of management to discuss employees who are on "The Blood Action List." This is a list of all employees whose blood-lead level is higher than 40 micrograms lead per 100 grams blood. The objective of these meetings is to "determine why an employee has elevated blood level." This is done by reviewing recent work assignments and the number of overtime hours put in. According to the plant manager who takes part in these meetings, the results of the program show that "work practices and personal hygiene are important factors when blood-lead levels are elevated."

Those workers targeted for training are taught by the plant's industrial hygienist. They meet once a month for one half-hour. They are trained about the biological effects of lead, how exposure can be controlled, the importance of proper personal hygiene, and how to correctly use a respirator. Whereas St. Joe's program emphasizes open-ended discussion, the Ethyl program uses a pre-established agenda to guide discussion.

This is a fundamentals program. The activities of Ethyl are designed to encourage workers to adopt practices and procedures prescribed by the company. The foremen, medical personnel and industrial hygienist are responsible for recognizing lead hazards in the plant and seeking remedies for them.

Ethyl's programs seem to have been quite successful, with blood-lead levels dropping significantly over the past 3-1/2 years (see Table 2). There was one period (January 1982-January 1983) where blood-lead levels jumped back up, but an intensive effort since then has brought blood levels to their lowest point ever. According to Terry Maples, who administers the program at Ethyl, "we relaxed after a strong year (1981) and everything shot up, so we put on our most intense effort yet and dropped them back down."

Table 2

Blood Levels at Ethyl Corporation's Baton Rouge Plant

	Percentage of workers having lead-blood levels of 40-49 micrograms of lead per 100 grams of blood (µgPb/100g)	Percentage of workers with higher blood levels:	
		50-59 µgPb/100g	60+ µgPb/100g
January 1980	28	14	59
January 1981	22	10	4
January 1982	12	4	0
January 1983	25	9	0
May 1983	11	0	0

BACKGROUND

ILZRO was founded in 1958 as an independent organization that, officially, in 1965 took over the research and development activities of the Lead Industries Association (LIA), the industry's main trade group. In the late 1960s, ILZRO began its environmental health research program by awarding grants and disseminating technical information to specialists in the field.

This role was greatly expanded in 1980 following the establishment of the OSHA lead standard. That year ILZRO obtained a New Directions grant from OSHA and extended its programs to include the training and education of management personnel. Funds for these activities between May 1, 1982 and April 30, 1983 came from both the government and ILZRO. The government contributed $58,000 and ILZRO used $71,349 of its funds. According to their 1983-84 New Directions proposal, ILZRO hopes to come up with 70 per cent of such funding in 1983-84.

As of June 1983, ILZRO's Environmental Health Department staff members were: Jerome Cole, SC.D. - Program Administrator, Chief Operating Officer, ILZRO; Robert Putnam, Ph.D. - Manager, Environmental Health; Rosalind Volpe - Assistant Manager, Environmental Health, and Neil Maresca - Training Coordinator.

APPENDIX

OSHA Requirements Concerning the Removal of Employees from Areas of Lead Exposure

	Removal* (in µgPb/100g blood)	Air Lead (in µgPb/m³ air)	Return* (in µgPb/100g blood)
After March 1, 1980	70	50+	50-
After March 1, 1981	60	30+	40-
After March 1, 1983	50	30+	40-

*For example, after March 1, 1983, if an employee's blood contains 50 micrograms or more lead per 100 grams blood he must be removed from all jobs where lead exposure exceeds 30 micrograms lead per cubic meter air until his blood level drops to 40 micrograms lead per 100 grams blood.